GREAT INDUSTRIES

OF

GREAT BRITAIN.

VOL. I.

ILLUSTRATED.

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CONTENTS.

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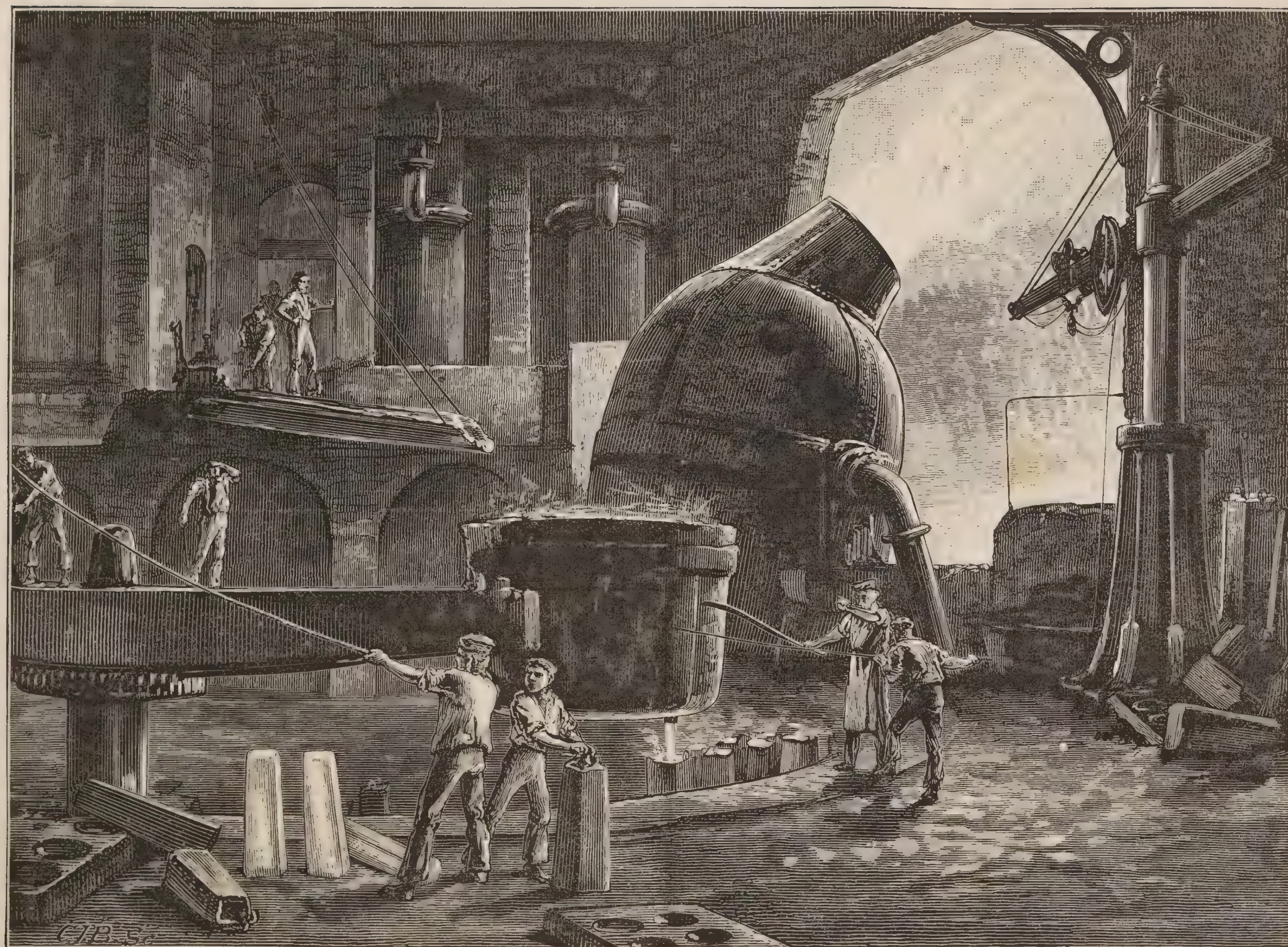

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INTRODUCTION.

GREAT BRITAIN and her brilliant dependencies form an industrial empire pure and simple. It is their business and function in the world to be industrial, just as it is the business of other empires to be agricultural or warlike. Year after year, what the Americans would call our "manifest destiny" is driving us faster and faster into this position—forcing us to withdraw from merely producing raw material, and to concentrate more and more our energies on the business of furnishing the world with that raw material transformed into finished goods. England is year by year becoming the artisan, the spinner, the weaver, the ship builder, the manufacturer, the engineer of the world. The world is every year more and more becoming a sort of colossal agriculturist, to render marketable whose productions is the business of the factories and the factory hands of England.

Now, as the imperial position of Britain depends mainly on the excellence with which she does her business as the great world-manufacturer, it is evident that every intelligent person ought to have some accurate knowledge of the subject-matter of our business as a nation. What would be thought of a military empire whose citizens kept themselves studiously ignorant of the use of arms?

Britain is an industrial State, and yet her citizens in the mass are comparatively uninformed about the nature, extent, relations, processes, and prospects of the Great Industries that rescue her overcrowded provinces from the gulf of relative pauperism. Were it not for her manufactures, England could not possibly buy food from foreign countries for her overcrowded population, because she would have nothing to offer in exchange for that food. In such a case every toiler in the land would have to desert all other occupations and strive to wring from the soil the barest sustenance. This rich realm would in fact be a nation of impoverished labourers doing nothing, and compelled to do nothing. but cultivate the land

for the sake of half-starving on the scanty and inadequate produce of their tillage. What stands between us and this melancholy, though, we trust, improbable, fate? We answer, Those Great Industries, to the development of which our countrymen during the last century have consecrated the national energies.

But we are sometimes told that our present supremacy as an empire of manufacturers may pass away, as did the commercial glory of Carthage, Genoa, and Venice. If we do not follow out our manifest destiny, and if, like them, we desert the fruitful field of commerce for the bloody and barren arena of military conquest, it is possible that our fate may be as theirs. If, again, we fail faithfully to serve the world as its manufacturer—if we do our work capriciously, badly, or dishonestly—we must lose our customers; and then with the downfall of our trade the annalist of the future may write our history in two wailing words—*Britannia fuit.* But that which would most contribute to bring these perils upon us would be popular ignorance, or, to speak more appropriately, absence of technical knowledge. If the citizens of this queenly commonwealth were as ill-informed about its true industrial interests as were the light-headed serfs of Carthage or Venice, the history of disaster might repeat itself. But, as a matter of fact, the attempted analogy is faulty. The glaring distinction between the ancient and modern commercial commonwealth is that in the latter knowledge of the true sources of national prosperity, and the necessary conditions of its continuance, is not restricted to any oligarchy of privileged capitalists, whose vaulting ambition in the former cases led nations to their ruin.

Still, although our countrymen generally are not altogether ignorant of the true interests, relations, and processes of our Great Industries, it would be absurd to say they know enough about these all-important subjects. We propose, therefore, in the pages that follow, to deal with certain great branches of manufacture, such as Cotton, Iron and Steel, Flax, Hemp, and Jute, Wool and Worsted, Pottery, and the like, which are interesting not only on account of the vast amount of capital they utilise, but also for the legions of patient toilers to whom they give profitable employment, and the scientific or artistic beauty of their processes of production. These gigantic Industries will be treated in no narrow spirit or dry-as-dust style. We shall address ourselves alike to the general reader and the artisan, to the student and the operative. The growth of these manufactures, biographical details of inventors and others whose names are associated with the different Industries, the rise and progress of the leading industrial centres, their wonderful romance, will be fully narrated, in addition to a popular and lucid description of all the processes of each manufacture, so that this Work will present a complete, clear, and comprehensive history of each of the Great Industries with which we propose to concern ourselves.

Then, again, there are many cognate subjects with which we shall deal in an easy, plain-spoken, homely fashion. For example, there is the great question of Industrial Sanitation—a question which we have thought it best to treat not merely in its legal, but also in its medical and physiological, aspects. Not forgetful of the subtle inspiration that lies in biography, we have also deemed it useful to include in this Work a series of personal sketches of great captains of industry—men whose careers may furnish many a wholesome lesson to struggling genius, and impart many a noble stimulus to gifted lads eager to scale "young Ambition's ladder." Nor shall we disregard the importance of the fact that England as a trading nation is now being closely pressed by foreign competition, the causes and inevitable results of which are but vaguely known—if known at all—to those most nearly interested in the matter. Our series of carefully-prepared papers on this most momentous question will be by design so put together that "he who runs may read." Above all things, they will, it is hoped, give a calm, a fairly judicial, and intelligible presentment of a subject too often obscured by the hot dust of controversy. We shall also devote a series of descriptive articles to many of those model establishments which have a reputation almost world-wide. And the interesting and instructive study of art and design in relation to the various manufactures of the country will be treated in a practical and attractive form. There are, besides, several other matters, all bearing directly upon the Great Industries of Great Britain, that will demand the most careful attention at our hands.

The aim of each writer will be to treat his subject in an unconventional manner, and to strain after accurate statement as regards matter; clearness, brevity, and brightness as regards style. The picturesque points, the social relations—in a word, the "human interest" of our Great Industries will receive at least as much prominence as their technical or purely scientific aspects. In short, no effort will be spared to make a solid and valuable contribution to the store of popular information in respect to our mighty theme.

IRON AND STEEL.—I.

THE BLAST FURNACE.

By William Dundas Scott-Moncrieff, C.E.

LORD PALMERSTON'S definition of dirt, as matter out of its proper place, is peculiarly applicable to the manufacture of iron, for the object of the blast furnace is simply to clean the ore. It is not that the substances mixed up with the iron are objectionable in themselves. In their own place they are useful and important, but in combination with iron they come under the Palmerstonian definition of dirt, and must be eliminated. To do this, the chemist has to be employed to analyse a small specimen of the ore. It is first of all necessary to know what impurities exist in it, and then to provide means for getting rid of them. But to effect this on a large scale is beyond the province and powers of the analytical laboratory, and so a vast crucible, where chemical changes are effected that require to be controlled with the greatest exactness, has to be called into requisition—and this is called a blast furnace.

Iron ore must be subjected to certain changes before it can be made subservient to the uses of men, and the nature of these changes must be varied to suit the different compositions of the raw material. Ores which contain the greatest quantity of iron with the fewest impurities were probably the first to be employed, because they were the most easily refined. Thus the foundation of all our discoveries was laid by prehistoric, perhaps antediluvian, smelters, who carried out extremely simple and primitive processes. Who they were is never likely to be known. The identity of the heavy-browed Assyrian, or the oval-eyed Egyptian, or the patient Hindoo, who first, after days and nights of watchful labour, produced the small but precious "bloom," has long since passed away. The romance of their early struggles, and the story of their failures and successes, lie buried in deeper oblivion than even their ploughshares and pruning-hooks. It must now be enough for us that what they found out they taught their children. In nearly all Great Industries an interval of thousands of years has elapsed between their first introduction and the discovery of those improved methods of manufacture which led to their sudden and continuous development. This is particularly the case with regard to iron smelting. At a future time, we hope to say something about Ralph Hogge, and Peter Baude, and John Darby, and also the shepherd-boy, John Thomas. Meanwhile, we ask the reader to follow us to the Black Country, and learn something of its great flame-crested towers, above which the glowing skies flicker and flash as if they reflected the blaze of burning cities.

The affinity of iron for other substances is so great that the pure metal, or "native ore," is seldom found in nature, and is therefore of little or no practical importance. It is in combination with oxygen, carbon, and carbonic acid that iron occurs most frequently, and it is with these substances—viz., protoxide of iron or sparry ore, peroxide of iron or hæmatite, and carbonate of iron or clay-band, or black-band—that the British ironmaster has principally to deal. At present, leaving an account of the different kinds of ore for another paper, let us try to understand what a modern blast furnace is, and what work it is meant to do.

The term "blast" is applied to those furnaces into which air is forcibly introduced for the purpose of producing rapid combustion. They are further divided into the two great classes of "cold" and "hot" blast furnaces—the air in the former being used at the temperature of the surrounding atmosphere; that in the latter being artificially heated before it is forced into the furnace. It was long before ironmasters could be persuaded that the hot blast made better iron, or even that it was more economical than the cold blast. Many of them argued that, because the furnaces seemed to work better and glow more brightly in winter than in summer, the blast should be always as cold as possible, and some of them even went so far as to cool it artificially. If there really was any truth in the statement about the effect of the seasons, it probably arose from there being less aqueous vapour and more oxygen, bulk for bulk, contained in the atmosphere in cold weather than in hot. Even now it is not easy to explain why the hot blast is superior to the cold. Probably the cold air entering the furnace had the effect not only of retarding but reversing certain essential chemical combinations. The most practical objection to the use of the cold blast is its chilling effect on the contents of the furnace, often amounting to a stoppage in the upward movement of the smelting process. In the face of these prejudices, Neilson, the discoverer of the hot blast, met with many difficulties and discouragements. Like nearly all other great improvements, its introduction was

so slow that its inventor was several times on the point of abandoning it; and it is, probably, as much to the enterprise of the few men who first adopted it as to the original merit of the invention that we are indebted for the vast saving in fuel effected by its use. The greatest advance that has been made in the process of iron smelting during the present century still dates from the time of Neilson's patent, which he obtained in 1824. Among the first great firms who proved the advantages of the hot over the cold blast, must be ranked the Coltness Iron Company, who, at their works in Ayrshire, constructed the most perfect apparatus for heating the air that had ever been employed. The statistics of these improvements are very interesting. As early as 1834—35, Mr. W. Clark, professor of chemistry in the University of Aberdeen, reported upon the comparative merits of the hot and cold blast; and some time afterwards M. Dufrénoy was employed by the Director-general of Mines in France to investigate the subject. His report seems to be principally based upon the result of experiments made at the Clyde Iron Works, near Glasgow, and as these speak for themselves, we will give them at length.

In 1829, the combustion being produced by cold air, the consumption for one ton of iron was—

	Tons.	Cwt.
Coal—first converted into coke, and then burned in the blast	6	13
„ for the boilers supplying steam to work the blowing engine	1	0
Total coal used	7	13

In July, 1833, the temperature of the blast being raised to 612° Fahr., and the fusion effected by *raw coal*, the consumption per ton of iron was—

	Tons.	Cwt.
Raw coal—burned in the blast . . .	2	0
„ used for heating the air on its passage from the blowing engine to the furnace	0	8
„ for blowing engine . . .	0	11
Total coal used	2	19

The high temperature of the stoves used for heating the blast caused them to wear out quickly. However, by arranging malleable iron pipes so that they are free to contract or expand with every change in the temperature, iron smelters can now deliver the blast at nearly double the temperature employed in these early experiments. At the Coltness Iron Works, the pressure of the blast is about four pounds per square inch, which represents the weight of about a hundredweight on the area of a man's hand—no inconsiderable amount, when it is considered that the air is sent into the furnace at the rate of ten thousand cubic feet per minute—a quantity which would fill a room fifty feet long, twenty feet broad, and ten feet high. The area of the heating surface in the apparatus employed is three thousand five hundred square feet, and the temperature of the blast is about 600° Fahr.

Of Neilson's great invention, it is enough to say that his first apparatus was of a very simple description. It consisted of a cylindrical retort of wrought iron, with a pipe leading into it at one end, and out of it at the other. This was placed over a fireplace, and the air was forced through it by a blowing engine. The specification of his patent is also famous as having been a very simple one. The invention is described as an "improved application of air to produce heat in fires, forges, and furnaces, where bellows or other blowing apparatus are required." He then goes on to propose "to pass the air through *suitably-shaped vessels*," where it was "to be heated *before it entered the furnace*." It was only after years of expensive litigation that Neilson gained any advantage from his discovery.* We cannot leave the subject of the hot blast without a quotation from a distinguished authority on all matters connected with the manufacture of iron. Sir William Fairbairn, writing in 1869, places the discovery of Neilson as the most conspicuous landmark of the last of five distinct epochs in the history of the iron trade. He says, "The fifth and last—though not the least important epoch in the history of this manufacture—is marked by the application of the hot blast, an invention which has increased the production of iron fourfold, and has enabled the ironmaster to smelt otherwise useless and unreducible ores; it has abolished the processes of coking and roasting, and has given facilities for a large and rapid production, far beyond the most sanguine anticipations of its inventor."

Let us now say something of those great blowing engines and air pumps which ply the furnace with its blast, and which are amongst the most imposing features of a smelting works. The different methods of supplying air are:—(1st) Placing the furnace itself in a position to allow of the wind acting upon it with violence. This is probably the earliest way in which rapid combustion was obtained. It was

* Neilson's descendants still represent the energy and perseverance which distinguished their father. Some of them are extensive ironmasters; and one, who is the head of the well-known firm of locomotive engineers that bears his name, is now engaged upon the introduction of pneumatic locomotion on our streets, under the writer's patent.

The Blast Furnaces at Summerlea by Night. *(From a Sketch by Mr. W. D. Scott-Moncrieff.)*

in this fashion that iron was first smelted in this country by the Romans. The remains of the waste cinders from their furnaces, from which the metal had been only partially extracted, actually afforded material for the operations of smelters centuries after the withdrawal of the Roman legions from Britain. These early furnaces were probably small conical structures having openings below for the draught to rush through, and some rude arrangement for regulating its pressure. They are usually spoken of as "air-bloomeries." The heat they produced could never be sufficient to completely melt the iron, so that they could hardly be called smelting furnaces. The sort of work they did would probably be to convert the ore into an imperfectly malleable iron, capable of being hammered into the different shapes required for the primitive implements and weapons of the time. Similar appliances are in use in some parts of "Savage Africa," but even there they have been improved upon. Imperfect as the "air-bloomery" was, it must be regarded as the precursor and parent of the vast and complex apparatus now employed by the modern smelter. (2nd) Producing a current of air by a fan, or some similar mechanism. (3rd) By the use of bellows. (4th) By means of a piston working in a cylinder, which draws the air in with one stroke, and forces it out by another. (5th) By the evolutions of a wheel, or fanner, which communicates a violent circular movement to the air, throwing it out by centrifugal force in such a way that it can be conveyed directly to the furnace. It is this last appliance which is almost invariably used for producing the blast in the cupola furnaces of iron founders, where pig iron is melted before being poured into moulds. But for the reduction of the ores in a blast furnace, a much greater blast is required, and the cylinder and piston apparatus is the one which is always employed. Practically, it is nothing more than an improvement upon a piece of similar mechanism which has been used from time immemorial by the savage inhabitants of Borneo.

Except that the material of which the apparatus is made is wood, instead of iron, the Bornean blowing machine is almost identical with those used in Great Britain till about the middle of last century. At that period the only available motive power, beyond that of animals, was water. Accordingly we find that the manufacture of iron was almost always carried on in the neighbourhood of some stream that could be utilised. The form in which steam was first applied was the atmospheric engine of Newcommen; but as it only acted in one direction, the action of the air pump was similarly defective. The improvements in the steam engine introduced by James Watt at once gave an immense impetus to the manufacture of iron, as it did to every other industry; and the increased amount and regularity of the blast produced by it soon led to an increase in the size of the furnaces, as well as in the productiveness of the materials employed. Among the triumphs of engineering there is not one that holds a higher place or presents a more imposing spectacle than a large blowing engine. No class of machinery is subjected to the ordeal of a more continuous strain. A single accident, causing stoppage of the engine, involves a loss in large works which must be calculated by hundreds and even thousands of pounds. Moreover, as the supply of air to the furnaces has to go on continuously —night and day, from Christmas to Midsummer, and from Midsummer to Christmas—the design, and material, and workmanship of the machinery must approach as near to perfection as is, humanly speaking, possible. The following description of a blowing engine of the largest class will convey a better idea of the subject than any more general account of them. It refers to the Kirkless Hall blowing engines, belonging to the Wigan Iron and Coal Company:—"The engine house is a handsome detached structure, about 75 feet long, 60 feet wide, and 72 feet high, and is entered by a large square tower, having an internal spiral staircase, with doors communicating with the several galleries in the engine house. On the top of this tower is placed a balcony, from which an extensive view of the surrounding country is obtained. The first impression on entering the engine house is one of complete astonishment, there being little of the appearance of an engine house to be seen. There are two handsome iron galleries extending round the whole of the interior; some feet below the first are seen the immense engine beams, each beam being about 38 feet long and weighing upwards of 20 tons. These beams, notwithstanding their enormous size and weight, move as easily and gently as if they were the merest toys, and this without the usual control of a fly-wheel, which in this instance is entirely dispensed with. The engine house contains three pairs of engines, each pair consisting of one high-pressure steam cylinder, 45 inches in diameter; one low-pressure steam cylinder, 66 inches in diameter; and two blowing cylinders, each 100 inches in diameter—one of the latter being placed about 17 feet above and

directly over each steam cylinder; the stroke of all these cylinders being 12 feet. The steam cylinders are worked together by means of the large beams before described, of which there are two to each pair of engines. The motion which works the valve gear is upon the low-pressure side, and is carried across the engine house beneath the floor, so that by means of one set of hand gear the eight valves of the two cylinders are easily controlled by one man, or worked by the engine itself, as may be desired. The six air cylinders, each weighing upwards of 25 tons, are placed upon stone piers; and on a level with the bottom of these cylinders is fixed the second gallery, which is reached by means of an iron staircase at each end." Blowing engines of this class are capable of discharging air at the rate of more than two hundredweight per minute, or six tons of air per hour.

The immediate adjunct of the blowing engines are the accumulators, into which the air is forced as into a reservoir. These have a capacity of several thousands of cubic feet—indeed they ought to have twenty times that of the air cylinders. They present the appearance of a huge ball of malleable iron plates riveted together in the form of a sphere. They are used for the purpose of steadying the blast, making it less jerky and more continuous than it would be if it were allowed to rush straight from the blowing engine to the furnaces. It must therefore be apparent that the blast furnace itself is after all but a comparatively small part of the complete apparatus required for smelting iron in great quantities; but as we have already deferred the description of it too long, let us proceed with it at once.

The usual form of a blast furnace is that of a truncated cone, rising to a height that varies in different districts from 40 to upwards of 80 feet from the ground. About 20 feet of this height is made up of a square base, which is about 30 feet on each side in the larger class of furnaces, and is pierced with arches to admit of the introduction of the blast and the removal of the slag and the molten iron. The arch which is used for the latter purpose is made larger than the rest, and forms the front of the furnace. In large works, as many as twelve furnaces are set in a row. They are all supplied with their blast from one gigantic blowing engine, while the raw materials, or "charges," which are to be dealt with are conveyed upon a gallery extending along the tops of the furnaces from one end to the other. As these enormous structures are not only subjected to a very high temperature, but have also to bear the outward pressure of their seething contents, it is necessary that their internal shape should be constructed with the greatest nicety, and that the materials of which they are built should be selected with the utmost care. The exterior of the furnace is generally constructed of sandstone, though sometimes gneiss, granite, and even limestone, are employed. In order to bind the masonry strongly together, it is clasped with bands of wrought iron. To prevent the ore and the fuel from pressing too heavily downwards upon the bottom, where the molten metal accumulates, the furnace is greatly contracted at the foot. The height of this contraction is about the same as its diameter, and it therefore forms a sort of square receptacle which is called the "hearth." Immediately above the hearth the furnace gradually widens out, forming what are called the "boshes." On the proper inclination of these to the other parts of the furnace a great deal of the support necessary for preventing the raw material from "choking" the blast must always depend. As the contractions in the interior of the furnace are made up of solid masonry, and as they are greatest in the vicinity of the most intense heat, an opportunity is afforded for protecting the exterior walls from an excessive temperature. For this purpose all the interior is built of firebrick embedded in fireclay, and a space of a few inches is left between the two structures to admit of the inner one contracting and expanding without injury to the rest of the building. From the top of the "boshes" the body of the furnace generally again contracts in a barrel-shaped curve, terminating, in a diameter of about 10 feet, at what is called the tunnel head, where it ends in a cylindrical structure, placed there for the purpose of protecting the workmen from the heat. Of course, the dimensions vary with different furnaces. Those that have been given are taken from a furnace at Dowlais Ironworks, in South Wales. The varieties of construction are also considerable. Some ironmasters, preferring to have a cheaper and less permanent structure, use cupola furnaces, which are built altogether of firebrick; while others add to the stability of such a furnace as has already been described by enclosing it throughout in a casing of malleable iron plates, riveted together, and pierced on four opposite sides for the admission of the blast and the removal of the iron. The nozzles which direct the blast into the furnace are called "tuyeres," and are made of cast or malleable iron, generally protected from the heat by the means of a current of cold water carried round their extremities to keep them cool.

EMINENT MANUFACTURERS.—I.

SIR THOMAS BAZLEY, BART., M.P.

By Robert Smiles.

MANCHESTER, the capital of the cotton manufacturing district, has been sometimes sneeringly referred to as "Cottonopolis," and the term "cotton lords" bestowed, sometimes satirically, upon the chief men of the district. But Manchester and Manchester men can well afford to overlook the ill-natured sneers of cynics and pseudo-moralists. There are many cotton lords, successful merchants, and illustrious workers, to whom epigrammatic slanders as to well-earned prosperity cannot possibly apply. Among them are to be found many who are as remarkable for their "fervour of spirit" as for their "diligence in business;" as notable for profuse liberality in the application of their wealth, as for the skill and industry exercised in acquiring it; men who are enlightened promoters of education and means for social amelioration; liberal patrons of literature and the arts; who, as philanthropists, have hands "open as day to melting charity," who "do good by stealth," utterly heedless of "fame." Others, it is true, besides "merchant princes," many poor men indeed, may be worthy of laudation. Wealth, in itself, is unworthy of worship. Still it must be admitted that the man who has devoted one portion of his energies during life to a particular department of business, and another to promotion of the public weal, and has been eminently successful and useful in both directions, has justly earned affluence and honour. Merited dignity is not degraded in being associated with wealth. If excellence of character and an exalted position are elements of lordliness, and requisites in one of "nature's nobility," Sir Thomas Bazley may be appropriately designated a "cotton lord." He retired from business in 1862 the admitted head of the cotton trade, not to enjoy the *otium cum dignitate*, to which he was so well entitled, but to devote himself to public life.

Sir Thomas was born on the 27th of May, 1797, at Gilnow, near Bolton. His father, a man who was distinguished by mathematical and other mental attainments, educated his son at the Bolton Grammar School, where the boy gave earnest of his success in after-life by the exercise of the commonplace but not common qualities of industry, attention, and punctuality, and by making in all respects the best use possible of his powers.

At an early age he was apprenticed to learn the cotton-spinning business with Messrs. Ainsworth and Co., successors to Sir Robert Peel and Co.; the head of the latter firm being father of the distinguished statesman. In 1818, when the factory system was as yet in its infancy, Mr. Bazley, then twenty-one years of age, commenced business on his own account at Bolton. It may here be mentioned that the Lancashire cotton factories are of various kinds—viz., spinning mills, weaving factories, and small-ware manufactories. In some instances spinning and weaving are carried on in one establishment. The spinning process covers a wide range as regards the quality of raw material employed and the fineness of the production. Sir Thomas's mills at Bolton and Manchester were fitted with the best machinery for spinning "high numbers" only, and the best raw cotton procurable was always used in them. It seems fabulous, although a fact, that his delicate machinery was capable, if operating upon carefully-selected material, of spinning from a single pound of cotton a thread of yarn from three to four hundred miles long!

At one of Sir Thomas's mills yarns were spun fine enough to make fabrics as delicate as the famed Dacca muslins, or the lace worked at the Ghent Beguinage. It was situated in Water Street, Manchester, where Sir Thomas commenced partnership in 1826. At the time of his retirement from business, he was proprietor of the largest concern of its class in the cotton trade, consisting of more than 160,000 spindles, employing 1,800 workers, who, with their families, would number more than 5,000 persons. His works employed nine steam engines, and contained a mile of shafting.

Commencing business so early as 1818, Sir Thomas Bazley may be regarded as one of the pioneers in the important modern creation—the factory system. No large employer of labour has had a clearer apprehension of his responsibilities than he; no one has done more to improve the condition and

increase the comforts of the factory operatives. At his large mills at Halliwell, he built schools for 400 children, provided a lecture room, a steam kitchen, and the means for many comforts. He was the first cotton spinner to pay the wages of his workpeople on Friday; in negotiation with Sir George Grey, then Home Secretary, he was instrumental in obtaining for factory workers the great boon of a Saturday half-holiday. His philanthropic liberality was well known among his workpeople and others in Manchester; on this point we write "concerning what we know, and testify to that we have seen." As a public man, Sir Thomas Bazley has always been clear and firm in his principles as a reformer and progressist; he has been ever ready, with courage yet moderation, to avow, advocate, and defend his principles. In 1839, free trade was a doctrine much reviled, but little understood; its champions were but a small phalanx, only a few of the great men who afterwards joined in the conflict having as yet come to the front. In that year the campaign was commenced at Liverpool by the great and lamented Richard Cobden; the subsequent "tribune of the people," John Bright; the witty and vigorous John Brooks, of Manchester; and Thomas Bazley, who on the occasion made right manfully his first public speech. He steadfastly adhered to the Anti-Corn-Law League, and munificently supported it until its triumph was achieved. As a public man, Sir Thomas Bazley has always been identified with proposals or action directed to the promotion of improved representation of the people in Parliament, economical administration, public liberty, and the freedom of trade and commerce.

In evidence of the high estimation in which Sir Thomas was held as a merchant and manufacturer, it should be mentioned that he was in 1845 elected President of the Manchester Chamber of Commerce, an office of distinction he held till 1859. He has been a director of the Chamber for nearly fifty years. This body consisted of more than 300 of the principal merchants and manufacturers of Lancashire. Its objects are to watch over the commercial interests of the district, and also those of the general public. Concerning Sir Thomas Bazley as a merchant, it must be enough to say that he had large transactions on 'Change, and that no member that frequented that wondrous hum was better known or more highly respected.

Touching Sir Thomas's action and influence locally, as a public man, space would fail for detail. There lies before us a number of reports of educational, religious, and benevolent societies in Manchester, of which we find him a liberal supporter. One important group of these must be made an exception of—Sir Thomas's action in relation to popular instruction. In all questions affecting education—elementary, advanced, artistic, or scientific—Sir Thomas has ever evinced the liveliest interest. He was for many years President of the Manchester School of Art; and President also of the Lancashire and Cheshire Union of Mechanics' Institutes, aggregating 40,000 members. His interest in popular education went even far beyond the very liberal provision he made for the instruction of the children of his own workpeople.

Manchester has been the seed-bed of the national education movement. Many years prior to 1847

the subject had been much agitated, and in that year it assumed consistency in a Public Schools Association, for the promotion of a system of popular instruction, to be supported by local rates, administered by local authorities, and to be unsectarian in character. This vigorous body aroused two formidable antagonists—the Church party, and the voluntaries—both of whom insisted on religious education; but the one went for rates, which the other opposed. Sir Thomas Bazley, although a good Churchman, joined the association, or unsectarian party, as soon as it was formed, and held to it loyally throughout. The secularists were taunted by their opponents, that the people would not accept the "Godless education" proposed. The answer to the taunt was the establishment of an absolutely free school for 300 boys, to illustrate the principles of the association. Mr. Bazley, with a number of other gentlemen, guaranteed the necessary outlay, and he and they kept it on foot for four or five years. The school was a complete success, but "my lords" of the Privy Council could not accept or assist it, and it could only obtain a grant and become a "British" school by reading the Bible. The educational conflict in Manchester was keen; but each party, while firmly holding to their own principles, more earnestly desired, as practical men, that the children should be got to school. The Rev. Canon Richson and his friends on the one side, and the Venerable Dr. M'Kerrow and his sympathisers on the other, coquetted, courted, and ultimately became one, under the guardianship of Mr. Bazley, in whom both parties had perfect confidence. Sir John Pakington, afterwards Lord Hampton, visited Manchester, and cemented the union, which did not just then bear fruit; but after a while fructified in Mr. Forster's Elementary Education Act of 1870. Mr. Forster, by the way, was a member of the National Public Schools Association before referred to.

In further evidence of the high estimation in which Sir Thomas is held by his fellow-citizens, it has to be said that in 1858 he was returned to Parliament, before the introduction of "three-cornered" constituencies, member for Manchester, without a contest; and at the next elections, in 1859 and 1865, he was at the head of the poll. He has sat for Manchester since 1858.

Sir Thomas married, June 2nd, 1828, Mary, second daughter of Sebastian Nash, Esq., of Clayton Mills, Lancaster, and has offspring a son—Thomas Sebastian, M.A., Trinity College, Cambridge, J.P., D.L. Sir Thomas is an officer of the Legion of Honour, is a magistrate and Deputy-Lieutenant for Lancashire, and holds other high dignities. He was a Royal Commissioner for the Great Exhibition of 1851, and was kindly received by the Prince Consort. He was a member of the Royal Commission in 1855, for promoting amalgamation of the laws of the United Kingdom; a commissioner for the Paris Exhibition of 1855; and was created a baronet in 1869.

In the House, Sir Thomas speaks little, but always votes straight, and no member gives less trouble to the "whips." There are few, if any, members in the House whose opinion carries as much weight on questions affecting currency, capital, cotton, and commerce—the two last especially. His views upon several important questions were very vigorously expressed in a paper he read before the British Association at Manchester in 1861. He appeared as the champion of the cotton industry, and right valiantly he acquitted himself. His scathing denunciation of slavery, his condemnation of Indian misgovernment, his irony touching the piracy of our inventions, the theft of our authors' works, and the prohibitory tariff of the United States, are things to be read *in extenso*, and that cannot be epitomised. Sir Thomas's writings are not numerous or voluminous, but they are all characterised by pithy, sound sense, and perfect knowledge of his subject. They include—"Cotton as an Element of Industry;" "Account of Barton Viaduct;" "The Labour of Life;" with articles in the "National Cyclopædia" on "Cotton," "Cotton Manufactures," and "Manchester;" and numerous contributions to reviews and periodicals, his most recent being a plea for establishing a new university in Manchester, in alliance with Owens College.

It should have been stated that the Cotton Supply Association, which has rendered very important service to the trade, owes its existence to Sir Thomas Bazley.

The personal qualities of Sir Thomas are such as combine, in the degree in which he possesses them, in few men indeed. As chairman, or member of a committee, no one has ever to wait for him. He is punctual, methodical, industrious, observant, prompt, resolute, but withal kindly and courteous, almost to a fault. If we had looked to his motto, "*Finem respice*" (Look to the end), this sketch would have been shorter; still, even as it is, the subject is shorn of its fair proportions.

Our portrait of Sir Thomas Bazley is taken from a photograph by Mr. Charles Watkins, of Parliament Street, S.W.

COTTON.—I.

THE RAW MATERIAL—EARLY HISTORY OF THE MANUFACTURE.

BY DAVID BREMNER, AUTHOR OF "THE INDUSTRIES OF SCOTLAND."

TO the poetic mind of Wordsworth a simple wayside wild flower suggested "thoughts too deep for tears." There is nothing so beautiful or even so romantic in the outward appearance of what the Manchester man calls his "raw material," and what the ordinary onlooker would recognise as a bale of cotton. Yet it is by no means devoid of picturesque associations; indeed, to a reflective person it ought to represent a teeming world of far-reaching suggestiveness; for is it not illustrative of the mysterious brotherhood of man, inasmuch as it is a sort of link binding together in complex connection the interests of vast armies of toilers in widely separated regions of the globe? There is no one of us, perhaps, who thinks much, if at all, of the swarthy, sweltering labourers in far-off tropical lands, whose lives are spent in wringing from the hot soil those glossy fibres which constitute the "raw material" of one of the greatest industries of the world. Nor are those toilers likely, as they pick the cotton pods, to have much in their minds those mighty "British interests," thousands of miles away, which the success or failure of their labours must make or mar. Little, we should say, does the South Carolinian negro reck of the great industrial hosts of Lancashire, who depend for the means of subsistence upon his exertions, and who, were they given to anxious reflection, would night and day be praying that none but propitious suns should warm, and none but the softest zephyrs kiss, the precious plants from which the contents of our cotton bales are culled. The touch of industry as much as that of nature "makes the whole world kin," and each bundle of cotton ought to suggest to us that however the colour of men's skins may separate them, white and black come into close alliance in the great brotherhood of trade and toil. There has been a time when such reflections would have led us on to unpleasant ground. It is not so long since the factory hand, stirred by passionate and sometimes not very reasonable agitation, was urged to regard himself as a sort of accessory to what John Wesley dubbed "the sum of all human villanies." He had to struggle hard with his conscience to forget that his and his children's subsistence varied in abundance with the fruitfulness or the failure of the slave grown cotton-pod. That time, happily, is now past, and the operative can pocket without the smallest unpleasant twinge the honourable wage which King Cotton pays to his laborious legions. Free labour is providing raw material for our cotton factories in various parts of the world, and every moment of the year scores of ships are ploughing their way towards England freighted with the precious commodity, and these pass on their way an outward-bound fleet carrying to all parts the product of English looms. Cotton has contributed largely to the creation of the grand position our country occupies among the nations of the earth, and we may point with pride to the great factories of Lancashire, with their hundreds of thousands of operatives, and their marvellous array of machines, and claim for them that they minister to the comfort and welfare of nearly the entire human race.

The history of this great industry is an exceptionally interesting one, and in proceeding to relate it, we pause to describe the "raw material." Cotton wool is the product of a family of plants belonging to the natural order of *Malvaceæ* or mallows. The generic name is *Gossypium*, and the species have been set down by various authorities at from three to about forty in number. Their characteristics vary greatly. While some varieties are mere delicate shrubs, little more than a foot high, other kinds attain the stature of trees, and range from twelve to over twenty feet in height. The shape and size of the leaves and seed-capsules, and the colour of the flowers, also present striking differences; but in this they are alike, that the seeds are enclosed in a fine glossy wool—the cotton of commerce. The value of this wool is determined by its fineness, length, strength, softness, equality of filaments, and freedom from knots and impurities; but the produce of only two or three species possesses those qualities in a remarkable degree. With cotton merchants and manufacturers botanical distinctions are not much recognised, the varieties of wool being designated by the names of the countries or districts where they have been grown. The principal sources of supply are thus roughly enumerated in the gross returns of imports:—"North America, Brazil, Egypt, British India, other countries." The first of these is the largest

contributor, usually sending out nearly six times as much as all the others taken together. British India, Egypt, and Brazil stand next in order. The most valuable kind of cotton is that which is cultivated upon the islets near the shores of South Carolina and Georgia, and known as "Sea-Island cotton;" and next in importance is that known as "Upland," pound of cotton is an article of daily manufacture. But besides yielding such good results when used by itself, Sea-Island cotton is mixed with varieties having a shorter staple, and enables them to be drawn out to a much greater degree of fineness than would be possible if they were used alone. The New Orleans cotton enters largely into our manufactures.

A Cotton Plantation.

grown in New Orleans. The "staple" or fibre of the former is from one and a half to fully two inches in length, and it is used for the production of the finer fabrics, as muslins and laces, and for sewing thread. The fibres are about one two-thousandth part of an inch in diameter, and may be spun into yarn of gossamer-like fineness. Some Manchester firms have applied the severest tests to the spinning capacity of this material, with the astounding result that a continuous thread, 1,026 miles in length, has been drawn from one pound weight of it. Yarn so fine that from 300 to 400 miles are obtained from a It is fine, soft, and white, and admirably adapted for making calicoes, velvets, fustians, &c. For certain purposes, the Brazilian varieties are also held in high repute, as are also those of Egypt. With regard to Sea-Island cotton, its great length and fineness have been clearly traced to the saline substances which the locality affords for the nourishment of the plant.

In determining the value of any sample of cotton, the merchant takes up a small quantity of it, presses it between his fingers, and watches to what extent the fibres are elastic or become entangled. He then

with the forefinger and thumb of each hand pulls the cotton apart again and again until the fibres arrange themselves parallel to each other, and he can ascertain their average length. During this process he also notes the regularity, smoothness, and other qualities of the material. The spinning quality of the wool depends on its length, fineness, spiral structure, and elasticity. Should the fibres be short and of a weak ribbon-form, they will not be highly esteemed by the machine spinner; though from wools of that description the Hindoo women are able, with their nimble and highly sensitive fingers, to produce a yarn of the most delicate tenuity. Some experts in the cotton trade acquire a wonderful degree of skill in determining the qualities of the wool. They have been known to tell the source and value of samples placed in their hands in a dark room, thus showing to how high a pitch the sense of touch may be cultivated. The cotton fibres terminate usually in keen points, and it is owing to this fact that cotton cloth, when applied to the raw surface of a wound or ulcer, causes much irritation, whereas, cloth that is made from flax does not. If the fibres of cotton be examined under the microscope, it will be found that they present the appearance of flattened cylinders, with a thickened border at either edge, and vein-like markings extending along the centre. They are invariably twisted, and sometimes take the form of spiral springs, which accounts for the readiness with which they combine in the process of spinning. In length the fibres range from half an inch to two inches, according to the variety of wool to which they belong, but all have a pearly lustre and smooth surface. The normal form of the fibre remains almost unchanged through all the processes of manufacturing, and is little altered even by being reduced to pulp and made into paper. Chemically considered, the fibre is pure cellulose, its elements being carbon and water combined in the same atomic proportion as they are in starch, but having a different molecular arrangement.

A Ripe Cotton Pod.

No fibre is put to a greater variety of uses than cotton. It is worked up into clothing materials of infinite diversity of texture, adapted to every climate, and becoming to wearers in every station of life. The leather-like habiliments of the navvy, and the fabulously-priced laces which adorn the daughters of fortune; the heavy-folded velvet train of the stage duchess, and muslins so fine that they have in Eastern hyperbole been described as "woven wind;" the net of the fisherman and the sail of his boat; the wick of the candle by the light of which these words are written, and, maybe, the paper on which they appear, have all been fashioned from the same material; nor do these by any means exhaust the contrasts that might be mentioned. There is not much similarity between a bunch of cotton wool and a piece of ivory; yet by special treatment the former may be made into billiard balls, and other articles, rivalling the latter in its most valuable qualities. In the hands of the chemist the wool shows itself susceptible of yet another change of character, and under the action of certain substances becomes converted into an explosive agent, many times more powerful than gunpowder.

Cotton Plant.

We have no record of the time when cotton was first used as an article of clothing by the inhabitants of those countries to which the plant is indigenous, but there can be no doubt that it was so used from a very remote period. When in full bearing, with its opened seed-vessels exposing their tufts of snowy

down, the cotton plant could not fail to attract early notice among the shrubs which adorned the haunts of primeval man. The lissom fingers which had learned to fashion garments from leaves and reeds could not long refrain from experimenting on the beautiful filaments so temptingly outspread. It would be found that by drawing out and twisting the fibres they might be formed into a thread of considerable strength; and subsequently the discovery would be made that by interlacing or weaving a number of threads together, a fabric of great lightness, warmth, and durability might be obtained. Thus we may suppose the foundation of one of the greatest industries in the world was laid by a people of whom no record remains, and who could not possibly foresee that their successful experiment would in the course of ages blossom into the colossal trade we now see, in which nearly the entire human race is either directly or indirectly concerned, and in which the capital employed must be reckoned by hundreds of millions sterling.

The first mention made in history of cotton relates to India, and occurs in the writings of Herodotus (445 B.C.), where we read that a species of plant flourished in that country which bore a fruit filled with a wool superior to that of the sheep, and of which the natives made cloth for their garments. Such garments being generally worn, leads to the conclusion that the cloth was no novelty even in those ancient times, and that the art of producing it had been known long previously. Nearchus, Alexander's admiral, in sailing down the Indus, and along the coast of Persia to the Tigris, in the year 327 B.C., also noted that the clothing of the Hindoos was "a sort of linen made from a stuff which grew upon trees." In the beginning of the Christian era, the cotton-shrub was carefully cultivated, and its produce converted into cloth in the Persian province of Susiana. The fact that cotton cloth has not been found on any of the Egyptian mummies, nor the cotton plant among their sculptures, is rather puzzling, as it is believed that the Egyptians were acquainted with the fibre from a very early period. Pliny, writing about the middle of the first century, says: "In Upper Egypt, on the side of Arabia, grows the shrub called by some gossypium, and by others xylon, from which cloths called xylissa are woven. The plant is small, and produces a fruit like a walnut, which contains a woolly down that may be spun into yarn. This cloth merits a preference over all others for its whiteness and softness, and is made into beautiful robes, which the priests of Egypt delight to wear." At the beginning of the second century, an important mart for traffic in cotton goods existed at Baroche, an Arabian port near the north-west coast of India. Thither Arabian vessels brought from various parts of India cottons, calicoes, and plain and flowered muslins. Subsequent writers speak of this export trade of India as having assumed considerable dimensions. Marco Polo, in the record of his travels in the East, in the latter half of the thirteenth century, makes frequent mention of cotton. He found it growing abundantly in Persia, and states that there was at Masulipatam an extensive production of the finest cottons to be met with in India. Among the earliest allusions to cotton in China is the statement that an emperor who ascended the throne in the year 502 wore a robe of this material. A century later, the cotton plant was cultivated as an ornament in the gardens of the Chinese; and it is a remarkable fact that though this reputedly ingenious people were aware that the cotton wool could be made into cloth, yet it does not appear to have occurred to them to apply themselves to the art until the eleventh century, when, from being a mere garden shrub, cultivated for the sake of its flowers, the cotton plant began to be grown in fields, and its produce to be worked into material for clothing. A great impetus was given to the incipient industry by the emperors of the Yuen dynasty, towards the close of the thirteenth century. They encouraged, and in some cases forced, the inhabitants to grow the plant, imposing on the provinces an annual tribute of cotton wool. In course of time the people came to see that the crop was a very advantageous one, and they devoted themselves to its cultivation without further nursing by the State. Cotton fabrics gradually came into fashion, and remain in favour till this day, the Chinese being among the best customers for the products of our looms. In Africa, as in India, cotton has been used as a material for clothing from time immemorial.

Turning next to America, it is recorded that when Mexico was first visited by Europeans, the people carried on a manufacture of cotton cloths of rare excellence, and of varieties of texture unknown in the East. For some purposes they wove cloths with different figures and colours, representing various animals and flowers; and the waistcoats of their grandees, which were made of cotton and the fur of hares or rabbits combined, seem to have been resplendent in gay colours. Among the gifts which Cortez made to Charles V. were a variety of cotton

mantles, some all white, others chequered with white and black, or red, green, yellow, and blue, rough on the outside, but inside presenting neither nap nor colour. Specimens of handkerchiefs, counterpanes, tapestries, and carpets of cotton, were also brought to Europe, and it is remarked that all these articles were more valuable for the workmanship than the material. Owing to the thinness of the cloth, it was customary to wear a multiplicity of garments. The women appeared in four or five vests and skirts of different colours, the inner ones being longer than those outside, so that a portion of each might be seen. The men wore mantles and vests after the same fashion. Evidence of the early existence of the art of making cotton cloth in Peru has been obtained in the ancient tombs of that country, where mummies have been found swathed in that material, and also in mixed stuffs in which cotton was used.

Spain was the first country in Western Europe in which the cotton manufacture was established, and during the thirteenth and two succeeding centuries the Spaniards enjoyed a high celebrity for the goods they produced. They were the first to make fustian, under the name of *fustaneros*, and are also credited with the first application of cotton wool to the making of paper. An Arabian author, who resided near Seville about the close of the twelfth century, gives a detailed account of the mode of cultivation and processes of manufacture. The Portuguese do not seem to have emulated their neighbours in the matter; but when they found their way to India by the Cape of Good Hope, they imported large quantities of cotton stuffs and muslins, some of which were sent to various European markets. The Dutch embarked in the same trade at a later period, and simultaneously began to manufacture cotton at home. Gradually the people of the Low Countries took to the new occupation, which they had carried to a high degree of perfection, when the religious persecution at the instance of the Court of Spain visited them, and many of them were driven from their homes. To refugees of this period we owe several important branches of industry; and one of the wisest acts performed by Queen Elizabeth was the encouragement she afforded to these people to settle in her kingdom.

During the fifteenth century the ships of Genca brought to our shores large freights of silk, wool, cotton, and paper. The trade afterwards passed into the hands of London and Bristol shipowners, whose vessels brought home from the principal Mediterranean ports silks, camlets, cotton wool, Turkey carpets, &c. The only use made of cotton wool in this country at that time, was in the form of candle-wicks. Owing to the mention of "cotton" in various early English works, as describing certain varieties of woollen fabrics, some confusion has prevailed as to the exact time at which the making of cotton cloths was begun in England. The woollen manufacture had been established in various parts of the country by the Flemings, who came over in the time of William the Conqueror, and had assumed a considerable degree of importance several centuries before any attempt was made to introduce the making of cotton fabrics; at least, we have no intimation of the existence of such a branch of industry until the year 1641. In Lewis Roberts's "Treasury of Traffic," printed in that year, the following passage occurs:—

"The towne of Manchester, in Lancashire, must also be herein remembered, and worthily for their encouragement commended, who buy the [linen] yarne of the Irish in great quantity; and, weaving it, returne the same again into Ireland to sell. Neither doth their industry rest here; for they buy cotton wool in London that comes first from Cyprus and Smyrna, and at home worke the same, and perfect it into fustians, vermillions, dimities, and other such stuffes, and then returne it to London, where the same is vented and sold, and not seldom sent into forrain parts, who have means at far easier terms to provide themselves of the said first materials."

Writing in 1662, Dr. Fuller remarks on the enterprise of the people of Manchester in buying cotton wool or yarn brought from foreign parts, and weaving the same into fustians, "to the good employment of the poor and great improvement of the rich therein, serving mean people for their outside and their betters for the lining of their garments."

Meantime, the East India Company had been importing considerable quantities of calicoes and muslins, in exchange for the woollen cloths of England; and from being regarded only as luxuries these came to be looked upon as necessary articles of apparel. In the year 1621 about 50,000 pieces of cotton cloth were imported into England, and sold at the rate of £1 per piece. Fifty years later the value of the import was £160,000. The first official mention of cotton wool as an article of import occurs in the Customs books for 1697, in which year nearly 2,000,000 lb. weight was landed at British ports. In the same year cotton goods to the value of £5,915 were exported. Certain

qualities of Indian cloth—notably the muslins of Dacca—were held in the highest esteem, owing to their remarkable fineness. This fabric is said to have been so delicate in its texture that it became invisible when spread on the grass and subjected to the action of the dew. This is the material that was described as "woven wind," and among other stories told concerning it we read that the Mogul Emperor Aurungzebe observed that his daughter was one day dressed in a semi-transparent tissue, and rebuked her for her indelicacy. She replied by assuring her parent that her robe was composed of not less than nine folds of muslin. Tavernier states that in the city of Calicut—whence the origin of the word "calico"—some cloth was made so fine that it "could scarcely be felt in the hand, and the thread was scarcely discernible." The hand spinners could draw a pound of cotton into a thread two hundred and fifty miles in length—a marvellous performance, certainly, but one which, as we have already mentioned, has been greatly surpassed by the iron fingers employed in the Lancashire mills.

FIBRES OF COTTON, MAGNIFIED. (310 *Diameters.*)

INDUSTRIAL LEGISLATION.—I.

By JAMES HENDERSON, ONE OF H.M. ASSISTANT-INSPECTORS OF FACTORIES.

It may now be fairly said that the controversy which has been so continuously and bitterly waged in the United Kingdom as to the right of the legislature to impose limitations and restrictions upon free labour, is practically closed. Something yet remains to be done, it is true, in the direction of concentration and consolidation, for our factory laws as they stand upon the statute book are complicated, confusing, and in some degree conflicting. But there is no contention now about the principles on which laws of this kind are to be based. The success of our factory legislation during the last fifty years has convinced even the most strait-laced political economists that there are some things which may prove to be highly expedient, although they may not be strictly lawful if tested solely by the canons of a theoretical science. All dispute as to the right of the State to interpose and protect its subjects from influences which are likely to prejudice either their physical or moral welfare is now at an end. The limits of such interference are admitted to be simply those of expediency. In other words, the existence of the evil influences complained of being proved and established, it is not only within the right of the State to interfere, but it becomes its duty to provide a remedy which will be at once practical and efficacious. We have seen this principle of action universally acknowledged by our legislature in later years, not only in the laws passed for regulating employment in industrial occupations, but also in those which have for their object the promotion of elementary instruction and the improvement of the sanitary condition of the people, whether they dwell in town or country.

To review the history of those causes which have created this great change in public feeling and public sentiment will be found both interesting and profitable, because while so doing we shall really trace the history of the social progress and advancement in civilisation of the people. And now that all difference of opinion as to the expediency of factory legislation is at an end, we feel free to criticise its progress and development without reference to the angry and excited discussions which it raised. To the impartial observer of the present day, it does appear extraordinary that so much difficulty should have been experienced by those who interested themselves in the cause of the over-worked factory operatives in inducing Parliament to take efficient action, so as to remove the abuses of which they complained. No one can doubt that any body of philanthropists who could present such a case supported by such incontestable evidence as was adduced by the advocates of the Ten Hours Bill to the House of Commons of

the present day, would receive a very different amount of support to that which was accorded those who pleaded the cause of the factory children through many long years of discouragement, disappointment, and delay. But it would be obviously unjust to apply the knowledge and experience which we now possess upon this important economical question as a test by which to measure the value of the opposition offered to the passing of the first Factory Acts. It is really difficult for us at present to understand and appreciate the social condition of the great mass of the people of this country less than forty years ago. Now that we have efficient public elementary schools established even in the remotest corners of the land, it is indeed difficult to comprehend how Mr. Leonard Horner, one of the first factory inspectors appointed, could have had it in his power to report, so late as the year 1843, that in an area of eight miles by four, embracing one of the most enterprising and populous districts in Lancashire, and comprising the boroughs of Oldham and Ashton, with a population of 105,000, there was not at the date of his then last quarterly report one public day school for the children of the operative classes! No fact that we can adduce, probably, can give a better conception of the extraordinary and rapid progress we have made in the matter of public education within the memory of men who have not yet passed the meridian of life. The ideas entertained by the generation immediately preceding our own on the subject of social refinement were very different indeed to those which now prevail. There is still, no doubt, great room for improvement; but when we read occasionally of some exceptional outburst of depravity and debauchery among the depraved and ignorant workpeople of a particular district, we must not forget the fact that in the boyhood—possibly in the early manhood—of the people engaged in these disgraceful proceedings, such scenes were of weekly—ay, even of daily—occurrence. Forty years ago, the amusements of the masses of the working population in the manufacturing districts were of the most cruel and debasing character. Such of them as were not actually vicious were disgusting and degrading, and when at present indulged in are made the subject of censure in every newspaper in the kingdom.

We desire to make one other observation before discussing the history of the factory legislation of this country in detail. It is to the effect that the successful termination of the agitation in favour of legislative restrictions cannot justly be claimed as due to the special efforts either of a social class or of a particular political party. It is a fact which reflects the highest credit upon the large capitalists and employers of labour in this country, that from the very beginning of the agitation onwards, men of this stamp were always to be found foremost among those who sought to mitigate the sufferings of the factory operatives by legislative interference. The first man to raise his voice successfully in the House of Commons on the subject was Sir Robert Peel—the first baronet—and he was a large employer of factory labour; and as we trace the history of the movement downwards, we shall always find among the prominent advocates for restrictive legislation large-hearted and liberal-minded employers, whose interest it might reasonably have been supposed would have induced them either to take an opposite view, or to remain neutral. With still less reason and fairness can it be asserted that the success of the factory agitation is to be credited to any particular political party. Its leaders continuously disclaimed any such idea, and, indeed, the whole history of the movement disproves it. The various Factory Acts which now stand on the statute book have been passed now by a Liberal and now by a Conservative Government, and the influence which has mainly determined this result has been the accident of either party holding office at the moment when public opinion was prepared to make another step in advance towards further restrictions. Once, and once only, in the course of its history, did the factory question raise an issue which involved the fate of a Ministry. This was in 1844, when the important factory law of that year was under discussion. The Bill had been prepared and introduced by the Government of which the late Sir Robert Peel was the head, and the supporters of the rival measure—the Ten Hours Bill—having defeated the Administration on a division in the House of Commons, the Premier made the question one of confidence or no confidence in the Government of the day; and having thus appealed to his followers, was enabled to reverse the decision of the House, and to carry his measure substantially as it had been first proposed, so far as the limitation of working-hours was concerned. But an examination of the division-lists, even on this occasion, shows clearly and conclusively that the question was not regarded then as a party one. Whigs and Tories are found fairly well intermingled among the "ayes" and "noes." Indeed, the factory operatives of Lancashire and Yorkshire exercised the most powerful influence in effecting their own emancipation. They were aided, it is true, by a

noble band of philanthropic men, who, irrespective of politics, or of creed, or of social position, gave a consistent and steady support to those schemes of legislation which were proposed with the view of lightening the burden imposed upon women and children by the excessive hours of toil exacted from them when employed in the factory. Some of these men are happily still spared to us, and their public career would alone be a sufficient answer almost to the attempts which have from time to time been made to attribute their humane zeal to narrow party motives.

The factory system and the necessity for a factory law had a common origin. They were the results of the introduction of machinery, and of the substitution of mechanical power for hand labour. The inventions which distinguished the latter part of the eighteenth century inaugurated a new era in manufacturing industry. Up till the year 1760, the machines used in the manufacture of textile fabrics were of the most primitive and simple description. The processes of spinning and weaving were, as a rule, performed in the same cottage, the females with their distaffs or spinning wheels preparing the yarn for the men, who worked it up into cotton or woollen cloth by means of the hand loom. But little advance had been made in the capacity or efficiency of these mechanical contrivances from the earliest period of history, and there was but little to choose between the primitive spinning wheels and hand looms of India and those in use in our country at the time we are now speaking of. The introduction of the cotton manufacture into England gave an important impetus to the demand for textile manufactures; and the importation from India of the beautiful fabrics produced from this material in that country no doubt proved a powerful incentive to inventors. The distaffs of cottage spinsters proved wholly inadequate to supply cotton yarn either of the quality or in the quantity which the rapid growth of the trade demanded. So slow was the process of spinning by the hand wheel that a single family was quite unable to keep a weaver supplied; and the latter, in addition to being compelled at times to pay an exorbitant price for weft, would not unfrequently have to travel three or four miles of a morning, in order to collect from different cottages sufficient to keep him going for the remainder of the day. In these circumstances, very naturally, improvements in spinning were first aimed at and encouraged; and the credit of the earliest really practical invention in this direction is due to Mr. John Wyatt, of Birmingham, a patent for spinning yarn by means of rollers being applied for so far back as the year 1738. Twenty years afterwards, the principle of this machine was amplified and improved upon by a Mr. Lewis Paul, of Kensington; and ultimately, in the year 1769, it was brought to a still higher state of perfection by the celebrated Sir Richard Arkwright. In the following year, another important advance was made in the invention of spinning machinery by the introduction of the "Jenny," which was the conception of a man of humble origin named Hargreaves, a native of Blackburn, in Lancashire. The Jenny, as first patented, contained sixteen spinning spindles, but this number was ultimately increased indefinitely, until by the aid of machinery as many as one hundred and twenty were driven in one frame. One improvement followed rapidly upon another in the machinery adapted for textile spinning, but it is hardly within our province to trace in detail the development of this branch of the cotton manufacture. It is perhaps sufficient for our present purpose to say that by the close of the eighteenth century machinery in factories had so far superseded hand labour in cottages in the cotton manufacture, that the whole system and conditions of production were revolutionised. A mechanical power being an absolute requisite for the working of these novel machines, and the steam engine being but as yet imperfectly developed, every stream and watercourse which could supply power, in Lancashire and Cheshire, soon came to be studded with cotton factories. The rapid expansion of the trade kept more than pace with the increased productive power of the machinery; and as the factories were necessarily placed in many cases in remote and comparatively inaccessible districts, where there was but a sparse population, an extraordinary demand sprang up for children, young persons, and women, who were found to be not only quite capable, but peculiarly fitted to attend to, and to work the various machines now adapted to the cotton manufacture. A system of apprenticeship was established, and in order to supply the deficiency of labour, thousands of children and young persons were obtained from the towns and more populous localities of the country for the cotton manufacturing districts. The pauper children from the workhouses of some of the large towns were drafted in large numbers to the same localities, and apprenticed to the millowners under circumstances which were very liable to lead to grave abuses. The mills were often situated in remote and unfrequented localities: the owners of them in

many cases, if not actually non-resident, left the details of management very much to their overseers, who were paid in proportion to the amount of work done. Every element was here present which experience shows is liable to lead to gross abuses. Unprotected children, apprenticed for a long term of years to employers who were negligent or indifferent as to their treatment, task-masters whose hearts were hardened by avarice and the love of gain; and there followed, as a matter of course, all the evils of slavery without its one compensating justification—an interest in the physical welfare of the slave. As early as the year 1796, complaints began to appear in the public journals respecting the cruel treatment to which the factory apprentices were exposed. There were, of course, many honourable exceptions among the employers—men who had a regard both for the moral and physical welfare of the children on whose behalf they had assumed a grave responsibility; but it is impossible to read any contemporary description of the condition of the factory population at this time without feeling convinced that there was a great deal of oppressive overwork, no small amount of cruelty, and a very general neglect of everything which would be likely to improve the morals or add to the social comforts of the wretched children who were thus helplessly sold into bondage for a long term of years. As the demand for manufactured goods increased, and as mills were multiplied, the evils of this system grew to such a degree that at last they attracted the notice of the legislature.

SHIP BUILDING.—I.

SHIP YARDS AND THEIR WORKERS.

SHIP-BUILDING establishments, as well as ship building, have been revolutionised by the introduction of steam power, iron, and steel, in the construction of vessels. Into the last half-century have been crowded changes in the sizes, forms, and propulsion of ships, compared with which all previous changes sink into insignificance; but there yet survive types of ships and methods of work closely resembling those in vogue at the commencement of this century, or even at an earlier date. The wicker-framed, skin-covered coracle which was used by the ancient Briton still lingers on in use on the rivers of Wales. The coasters and small craft of the present day are very like those employed in similar duties hundreds of years ago. And notwithstanding the wonderful development of steam navigation, many vessels of the older types are still engaged in distant voyages, sharing the foreign trade with steamers and improved classes of sailing ships. Great varieties also exist in the ship yards of the country. In many a small seaport, as well as in some of the centres of ship building, may still be seen ship yards as destitute of machinery and mechanical appliances as were the ship yards of the seventeenth century. Yet such establishments can exist, and to a limited extent do useful work, side by side with the well-equipped modern ship yards wherein the magnificent mail steamer or ponderous ironclad is constructed.

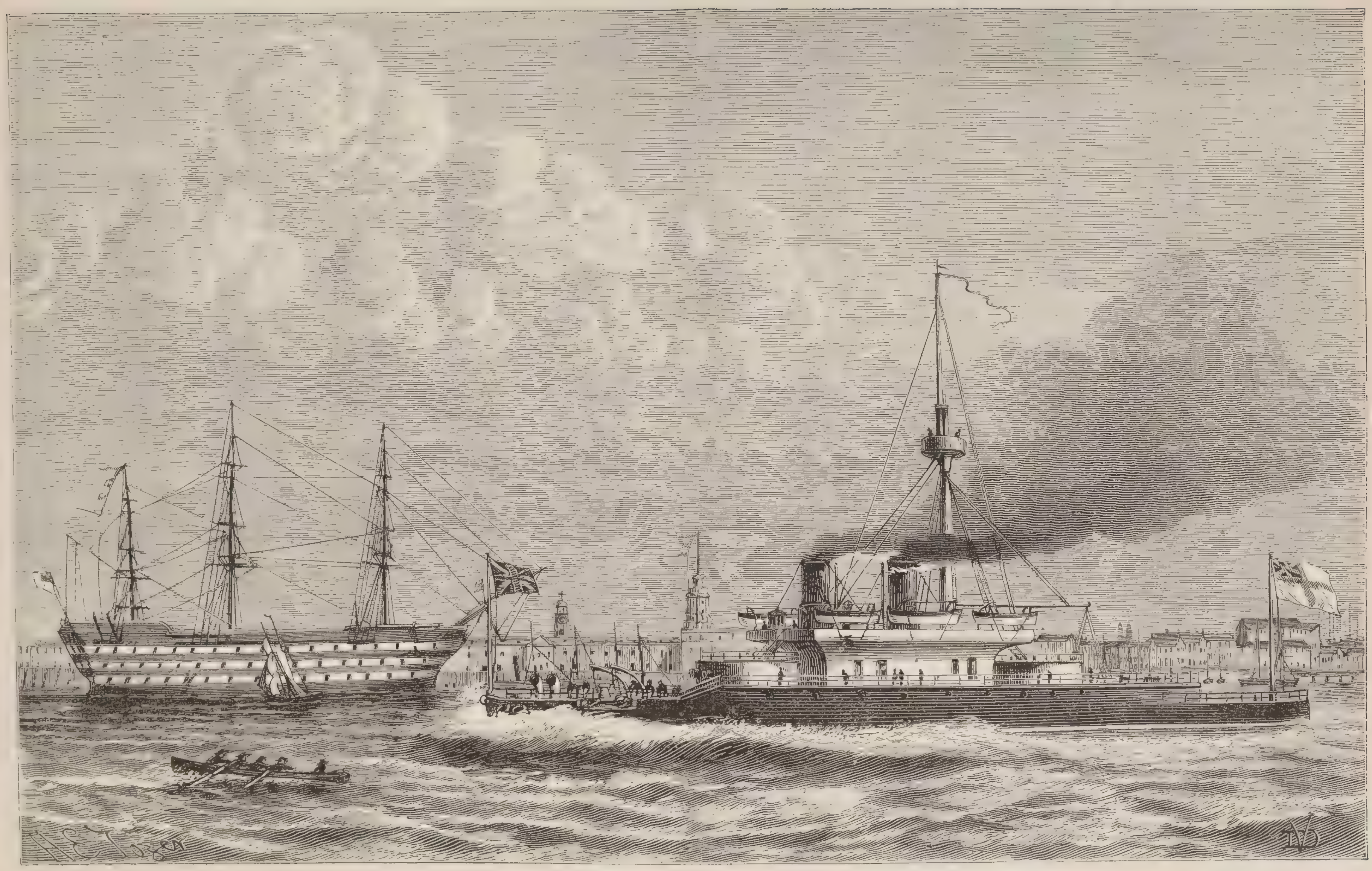
Many of our readers have probably stood and overlooked the workers in one of these simple yards, at one of the smaller seaports. The central feature in the scene has been some tiny vessel, partially completed, perhaps—a mere skeleton of keel and ribs. The working staff consists of a few men, and a relatively large number of boys. The raw material, in the form of rough logs or trees, lies heaped in some convenient corner, or scattered over the yard; and from this raw material the skill and handicraft of the workers have to produce a finished ship. If the visitor inquires their trade, he will be told that these men are *shipwrights*, whose duties are really multifarious. At one time busy as a *sawyer*, cutting the rough logs to the approximate shapes required for keel, ribs, planking, or beams; then, as *shipwright*, deftly wielding axe or adze, and trimming the timbers to their finished forms; next arranging some simple apparatus for hoisting the several pieces of the frame into place, and securing them there; until at length the skeleton is complete, with the deck-beams lying side to side; then shaping the supple planks which are to enwrap the skeleton and form its skin, bolting and fastening these planks to sides and decks; as *caulker*, driving the oakum into the seams between the planks, and "pitching" the outer surfaces to make them water-tight; or as *joiner*, completing the internal fittings. Shipwrights also make the masts and spars, and sometimes

actually rig the ship; which is "from keel to truck" their work. But more commonly the shipwright seeks for the aid of other tradesmen in some stages of the work. The *blacksmith* supplies him with ironwork of various kinds; the joiner completes the cabins and fittings; the plumber fits pumps and pipes; the rigger and sailmaker complete their special works. Even when thus aided, the bulk of the work of building devolves upon the shipwright, and he alone has to bear the great and final responsibility of the launch, when the finished ship slides into the water, and floats away ready for service in any sea.

The rude appliances of the "'long-shore shipwright" may, perhaps, appear almost contemptible to an observer familiar with the larger operations of a well-equipped modern ship yard. In these numerous rough-and-ready establishments is, however, to be found an element of national strength; for they are nurseries of skilled workmen, who pass out from them to other and larger establishments. Skilled hand labour must always be required in connection with ship building, even when the fullest possible use has been made of machinery. The final shaping of the numerous pieces forming the structure of a ship, their arrangements, adjustments, and combinations, cannot be performed by machinery independently of skilled labour. Nor should it be forgotten that ship building in the minor seaports helps to keep local interests alive. The ships built are commonly owned in these ports, and are manned by natives of the places, who constitute as hardy and daring a race of seamen as can anywhere be found, and whose services have often been most valuable in time of war.

Let us now conduct our readers, in imagination, to what may be termed an ordinary iron ship yard, where the business is exclusively that of building iron merchant ships, not of repairing them or constructing marine engines. The din and clatter of the works will be heard long before they are reached, indicating the great changes in ship building that have accompanied the substitution of iron for wood. On entering, the visitor, fresh from the survey of an establishment where wooden ships are built, will find some difficulty in understanding the processes in operation; but ere long he will detect many important differences, and grasp the reasons for their introduction. First of all, he will not fail to note that the materials for the iron ship are supplied by the manufacturer to the builder of approximately the forms and dimensions required; so that the work of preparation is much lessened, as compared with that incidental to building wooden ships. Take, for example, the ribs. In the wooden ships it is a matter of careful and skilful workmanship to saw or hew out of the rough logs appropriately curved timbers, many of which have to be combined to form a single rib. In the iron ship, the angle-bars used for the ribs are simply heated in a furnace, and then bent to the required shape, each rib being formed by the simplest possible combination of two or three such bars and a piece of plate. Similarly, the deck beams, which in a wooden ship require a large expenditure of skilled labour in their formation, are in the iron ship supplied almost in the finished form. And in many other cases that might be mentioned the same thing is true; the iron maker anticipates the wants of the ship builder, and saves him a large amount of preparatory work.

Another striking point of difference between the iron and wooden ship yard is the more extensive employment of machinery in the former. Iron plates and bars are punched, sheared, drilled, planed, and bent by simple and suitable machines, managed by unskilled labourers. Skilled labour consequently occupies a much less prominent position in relation to unskilled labour in the construction of iron ships. A few skilled workmen, assisted by many labourers, suffice to perform operations corresponding to those which in the wooden ship would be accomplished by many shipwrights. Furthermore, there is a much greater sub-division of labour in the iron than in the wooden ship yard. We have already seen how multifarious are the duties which the shipwright undertakes; and that he virtually, as his name implies, builds the wooden ship, other tradesmen simply aiding in the fittings and equipments. But in the case of an iron ship, there is no correspondingly prominent artificer of the "general utility" type. The *plater* is, perhaps, the leading workman, for he bends the ribs, fashions the plates, arranges the fastenings, and is responsible for the preparation and combination of the various pieces in the structure. When this preparatory work is over, the plater gives way to the *closer*, who makes the final adjustments and arranges temporary fastenings which hold the parts together in their proper relative positions, until the iron rivets forming the permanent fastenings are put in by a third set of workmen, the *riveters*. These men are followed by the *caulkers*, who make the seams of the iron skin water-tight; and after them come the *painters*, who clean and coat the surfaces of the plates and bars with cement or paint. The forged ironwork



Battle Ships of 1800 and 1875—Nelson's "Victory" and the "Devastation.'

of the hull is prepared by the *blacksmith*, who plays a more important part in iron ship building than in wooden ship building. The woodwork, which forms a minor but still an important feature of an iron ship, is also subdivided between the *shipwright* or *ship carpenter* and the *joiner*. Fittings of cabins, store rooms, and other internal spaces, belong to the joiner; the shipwright lays the wooden decks or platforms, fits the wooden linings, or "ceiling," on the sides, and does other work closely connected with the hull. Minor trades also contribute to the completion of iron ships as well as wood ships. The *plumber*, the *founder*, the *fitter*, the *rigger*, the *sailmaker*, and others, are brought into action; and in the case of steam ships, the marine engineer has exclusive control of the important work of building and fitting boilers, machinery, and propellers.

The sub-division of labour in an iron ship yard is even more minute than would appear from the foregoing sketch, and it is associated with a system of *sub-contracting* which deserves to be noticed. These sub-contractors are usually skilled workmen, who have some capability for management, and who employ their own gangs of men. They make engagements with the ship builder to perform certain parts of the work at certain rates of payment, the ship builder placing his machinery and plant at their disposal, while the sub-contractor finds all the manual labour, and pays his assistants. The builder is thus relieved of much labour in arrangement and supervision; instead of having to oversee every detail in the process of building a ship, he has simply to inspect, accept, or reject finished work. Very rapid progress is also possible under this system. Sets of workmen, who are continually employed upon one description of work, acquire wonderful facility in its performance; and this favours cheapness as well as rapidity of production. On the other hand, the system has one serious drawback: it tends to prevent the introduction of improved methods of construction, by means of the opposition which the sub-contractors make to any departure from their well-accustomed ways.

First-class ship-building establishments differ from the ordinary iron ship yards, which have been briefly described, not merely in their extent and the magnitude of their operations in building ships, but also in the fact that in nearly all of them *marine engineering* is carried on. There are a few exceptions to this rule; but the advantages of associating the two industries must be obvious. Steam ships are gradually gaining upon sailing ships: the demand for steamers is great and increasing. In the design and construction of steam ships, the naval architect and marine engineer must of necessity work together, if success is to be achieved. It is highly advantageous to have both departments under one head, whose direction secures that harmonious action and mutual help which are essential to the best results. And, further, some branches in each department can be made available for the assistance of the other, such as the blacksmiths' shops, the foundry, and the machine shops. But while these kindred professions are thus closely united, they are not blended into one in this country, as they are in France and Italy; nor does it seem desirable that this should happen.

A third department, devoted to the repairs and alterations of ships and engines, is contained in a few of the first-class establishments. So far as the machinery is concerned, there is no difficulty in carrying out this arrangement, as the same factory and plant serve for building and repairs. But for repairs or alterations to the hulls of ships, it is necessary to secure a thorough survey of the whole surface of the bottom, and easy access for workmen to every part. In a tidal stream or harbour, and for small vessels, this end is accomplished very simply. The vessels are lightened as much as possible, placed in position when the tide is at full height, and, as the tide falls, allowed to ground either on the beach itself, or on a prepared "gridiron," formed of logs of timber laid parallel to one another, and having a fair surface to receive the ships. Where the rise and fall of tide is considerable, even large ships may be dealt with in this fashion, the workmen having access to the bottom at low tides. In the case of the *Great Eastern*, which was too large to enter any existing docks, the extensive repairs to her bottom, after she had run aground off the American coast, were thus effected:—Milford Haven was the scene of operations; the rise and fall of the tide in that place being exceptionally great, averaging more than twenty feet, and the beach there presenting a suitable site for the construction of a gridiron. The monster ship was brought into position on the top of a high spring-tide, and remained aground until the repairs were finished. This simple plan is not, however, generally applicable, while it is open to several objections. The operations of the workmen depend upon the tides, and are therefore liable to constant interruptions, and few facilities can exist, under the circumstances, for carrying on successfully large repairs or alterations. Hence it is usual to have recourse to this plan only in exceptional cases, or for small vessels;

and in general to resort to permanent and special appliances for withdrawing ships wholly from the water, and working under their bottoms.

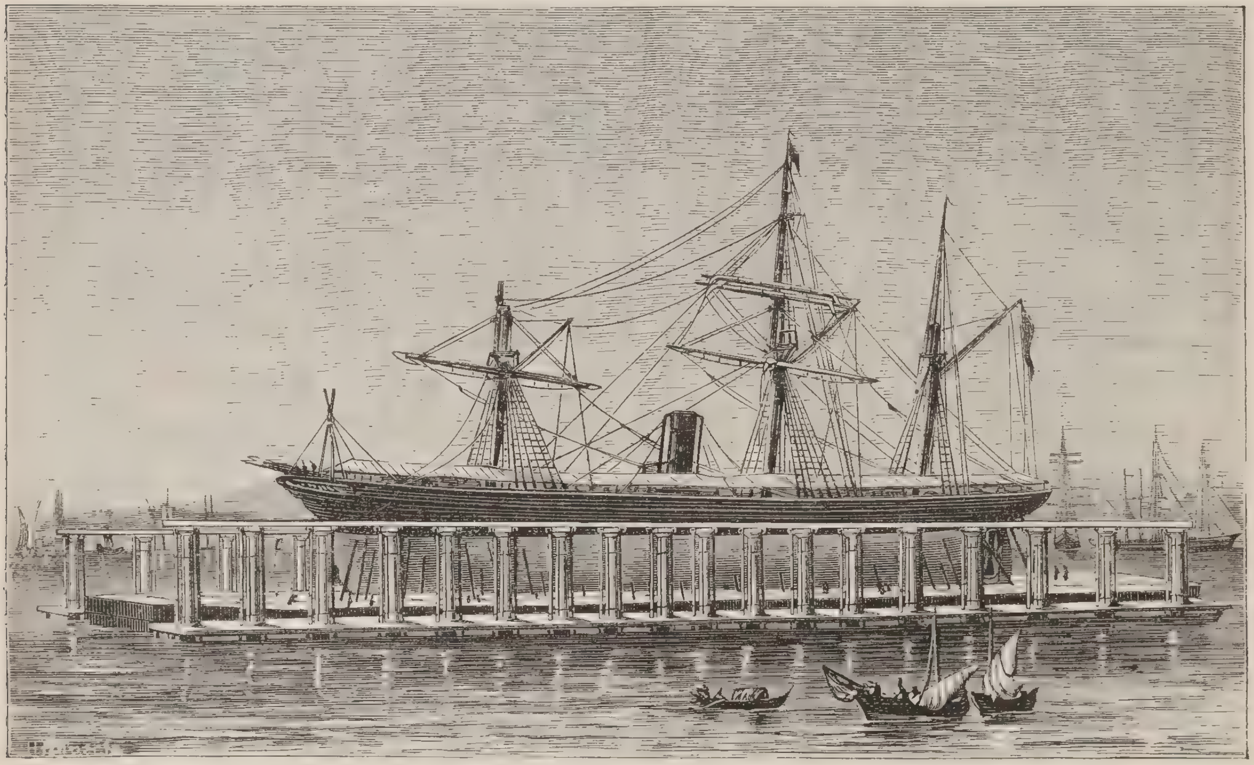
Dry docks, or *graving docks*, are the commonest means. To form them, large excavations are made with entrances from the sea or river, closed by gates or "caissons." When a ship is to be docked, the water is admitted to the dock by means of culverts, the gates or caissons are then moved back to clear the entrance, the ship is hauled in, and the entrance again closed. Powerful pumps, usually driven by steam power, are then set to work to remove the water from the dock. The ship grounds, and is "shored," or supported from the dock-sides, to keep her upright; and finally, when the dock is pumped dry, she is left in position for survey or repairs. Such docks are very costly; and in these days of rapid changes in the forms and dimensions of ships, it not unfrequently happens that a dry dock becomes partially useless, because its length, or breadth of entrance, or sectional form, makes it impossible to place vessels of new types within its gates. Alterations are often nearly as expensive as first construction, and hence there have arisen many plans for superseding graving docks by cheaper constructions, possessing greater elasticity in their accommodation. *Hauling-up slips* are largely employed for merchant ships, and with much success. A sloping slip-way is built, upon which a carriage can move up and down, supporting a cradle. When the tide is at full height, or the vessel is ready, the cradle is placed underneath her, and she is allowed to ground or rest upon it; then, by means of steam or hydraulic power, the cradle, carrying the ship, is hauled up high and dry. *Hydraulic lifts* have also been used in many cases. The ship is floated in between two rows of pillars, which contain hydraulic presses, by means of which strong girders, stretching transversely from pillar to pillar, can be raised. A pontoon is filled with water, and allowed to sink until it rests upon the transverse bearers, before the ship is brought into position. When she is there, the presses are set to work, and the bearers with the pontoon are raised, until it reaches the keel of the ship, and gradually lifts her out of the water. Meanwhile, she rests upon suitable blocks fixed on the pontoon; and when the latter is raised sufficiently high, the water in it is allowed to run out. The valves in the pontoon are next closed, and it is lowered until it floats, with the ship upon it; when it can be towed away from the lifting presses to any suitable locality. After the repairs of the ship are finished, the pontoon with its burden is towed back to the presses, and by a simple series of operations, corresponding in character to those described above, the vessel is once more set afloat. Mr. Edwin Clark is the inventor of this ingenious plan, which may be seen in operation at the Victoria Docks, London, and which has also been applied successfully at Bombay, Malta, and elsewhere. It has the great advantage that the expensive part of the apparatus—viz., the lifting presses, can be made available for any number of ships, the lengthy operations of repairing being carried on upon a simple and comparatively cheap pontoon.

Floating docks have also been used with much success in places suited to their employment. The general principle of all these docks is that they can be submerged sufficiently to enable ships to float into their entrance, and that then by some means the water can be cleared from the dock, or from chambers within it, the dock lifting and carrying the ship with it out of the water. On the Tyne, a very primitive kind of dock is used for tugs and small vessels. It consists of a wooden tray-shaped box, with gates at one end. The dock gates are opened when the dock is aground at low tide. As the tide rises, the water enters the dock, and of course it remains aground. At high tide, the vessel to be docked is floated in, and as the tide falls she grounds on the dock. When it is low tide, the dock is freed of water, and the gates are closed; when the tide rises again the water cannot enter the dock, nor reach the vessel within it. This plan is only of very limited application. Ordinarily, the floating dock has chambers, to which water is admitted when the dock is to be immersed more deeply. When the ship is floated in, pumping power carried by the dock is brought into operation to clear the water from the chambers; the dock, with the ship upon it, is thus made to float at a higher level. In some cases, the water chambers are placed high on the sides of the dock, and filled with water by means of the pumps when the dock is being sunk more deeply; then, when the ship has been floated into place, it is only necessary to open valves in the water chambers, and to allow the water to escape. Time is thus saved when time is valuable, the operation of sinking the dock being proceeded with more leisurely. The most magnificent floating dock yet constructed was built some years ago at Millwall, and is now in use at the Royal Dockyard, Bermuda. Vessels weighing between seven and eight thousand tons have been docked there.

Besides these costly appliances for docking or lifting ships, there must be a special plant for some

part of the works incidental to repairs; and hence it commonly happens that such works are carried on in independent establishments. There are, however, as has been said, some first-class private yards, which comprehend all the necessary appliances for both building and repairs, with docks capable of receiving the largest ships in the Royal Navy and mercantile marine, and the means of giving such ships a thorough overhaul.

As an example of these fully-equipped private



Clark's Hydraulic Lift, Bombay.

establishments, let us take that originated by Messrs. Palmer at Jarrow-on-Tyne, now the property of a company. This ship yard is in some respects unique. The scope of its operations has been tersely expressed in the phrase—"Coal and iron ore come in at one end of the works; ships are launched, with steam up, at the other end." This is by no means an exaggeration. Magnificent blast furnaces extract the iron from the ore, and deliver it in the form of pig iron. Puddlers, working half-naked in front of scorching furnaces, convert the cast iron into malleable iron; steam hammers and the rolling mill turn it into plates and bars fit for ship-building purposes. So complete are the arrangements of this iron-making department, that the works can meet their own requirements, and supply materials to other ship builders. There are few, if any, other ship yards which make their own plates and bars, the usual practice being to purchase of the manufacturer. Engines as well as ships are produced at Jarrow, an extensive and well-equipped factory having been created for the purpose. Smitheries, saw mills, joiners' shops, and other accessories of the ship yard, exist on a large scale. There is also a magnificent dry dock, well adapted for surveys of the largest merchant ships, and good wharfage where ships can lie while receiving the finishing touches. All classes of ships can be produced and have been built, from the Atlantic mail steamer down to the tiniest river-craft, from the iron-clad war ship down to the small but dangerous torpedo vessel.

On the Thames, the Clyde, and the Mersey, ship yards may be visited which are little inferior in interest to that at Jarrow; in fact, some of them surpass it in the magnitude of their ship-building and engineering departments. In minor details, their practice may differ, but they have one object in common—the production of swift, safe, and seaworthy ships. The extension of iron ship building, the development of steam navigation, the supremacy of British shipping, and the commerce of the world, are all indebted to the enterprise of the private ship builders of this country.

HEALTH AND DISEASE IN INDUSTRIAL OCCUPATIONS.—I.

ARE THE INDUSTRIAL CLASSES NECESSARILY UNHEALTHY?

By W. Gordon Hogg, M.D., late Senior President of the Royal Medical Society, Edinburgh.

"CA' them lives o' men," said the Scottish fishwife of her "Caller Herrin'" in the old song. Is it a fact that many of the articles brought to us by the labour of other industrial classes besides the "fisher-folk" are obtained only at the cost of life, of health, or of suffering? If this be true, it must be interesting, and may be useful, to know what industries are unhealthy, why they are unhealthy, and what means may be adopted to save life or diminish disease amongst those who work at them. The dweller in a city or manufacturing town cannot expect to have the bright eye and the ruddy cheek generally associated with country air. But for all that the city artisan who is temperate and cleanly, and who occasionally "takes his missus for an airing" after work is over, or on holidays, may enjoy the physical side of life as much, or perhaps even more, than his agricultural fellow-labourer.

The average health of our large cities compares favourably, not perhaps with an ideal, but certainly with an ordinary or actual English country village. We must, therefore, not ascribe to any particular employment the disease which in any class, whether industrial or idle, results from dirt, drink, or bad habits. Many of the best athletes in Britain are constant dwellers in cities, and are from day to day, and from year's end to year's end, closely engaged as manual labourers in various industries. From the great manufacturing centres come working men of every grade, who rank high among celebrated runners, walkers, cricketers, and oarsmen. What philanthropists and sociologists anxiously discuss in these days in spite of such obvious facts as those now mentioned, is this:—Suppose a healthy rustic resolves to exchange the cheerful splash of the village mill-wheel for the roar and whirl of the steam factory, does he necessarily undergo physical degeneration, and become diseased? Had this paper been written thirty or forty years ago, the answer which must have been given would be a melancholy one. The dark record of that bygone time tells of long hours, bad food, ill-ventilated workshops, and no attention paid to health either by masters or men. The face of the factory hand who had thus migrated from the country to the town mill soon became pale and anxious, his chest flat, his body bent, and a premature sick-bed often, if not usually, terminated a cheerless life. The factory worker of that time could, by what medical men sometimes call "physiognomic diagnosis," be told at a glance. Be he as clean or temperate as possible, yet what may be called necessary disease—that is, disease brought on him by the conditions in which he wrought, cut him off. But by factory legislation, and by intelligent co-operation, on the part of employers, with the administrators of the Factory Acts, a marvellous change has resulted. Well-lighted and well-aired factories, means for carrying off irritating dusts, shorter hours of work, the opening of public parks, recreation grounds, wash-houses, and improved dwellings in the great centres of industry, have brought about what might almost be called a revolution in the sanitary condition of the working classes. So that, in the majority of our great industries, a worker may be nearly, if not quite, as healthy and free from disease as a professional man or merchant. Still, in spite of all this, there remains the fact that there are yet in existence some diseases specially associated with employment in certain particular industries. Why is this so, and whose fault is it? In some cases, appliances for protecting the worker have not been adopted. In others, the action of the numerous and vigilant inspectors of factories and workshops is evaded by the masters. Again, the men sometimes perversely refuse to use the preventive means provided for them. For instance, knife grinders suffer from a lung disease caused by steel and stone dust entering into the minute air-cells of the lung, and breaking up the organ. Fans were applied to create draughts that would suck away this dust from the grinding-wheels. But some of the men foolishly objected to use them, because they argued that if the lives of the grinders were lengthened they would not go out of the world fast enough to make room for others! The British workman, like the rest of his countrymen, is often opposed to "new-fangled inventions" out of what one of the American humorists calls "sheer cussedness," no matter whether these inventions directly or indirectly benefit him. Whatever theoretical objections may exist to the inquisitorial functions of Government inspectors, there is

no point from which they can be so strongly defended as in the matter of industrial health. Still, much remains to be done. It will be our object in these papers to show what special diseases associated with industrial occupations remain as a blot upon our public sanitation, and to suggest, if possible, how they may be avoided.

Of course, if men or women start at an early age with bad physiques, hard work of any description is certain to injure them. This is a most important point to keep clearly in view. For instance, if children are sent to work at an early age, before their pliant frames are set by nature's moulding, and should any special attitude in "minding" or tending a machine require to be kept, their bodies become stunted or deformed. Stooping, raising the shoulder, craning the neck, or long standing are markedly deleterious. Had work been commenced later in life, the risk of suffering from such causes would be lessened, if not altogether removed.

To go back a stage, when a mother is allowed to leave her infant of a month old in the care of a "nurse-tender," and go to the factory, she herself is in a condition fraught with peril. But what of the babe, who may one day blossom into a factory hand? The child is, perhaps, dosed with soothing-powders and syrups containing opium, to keep it quiet. A bottleful of some starchy compound, pleasingly denominated "artificial food," dissolved in milk and water, is placed on its pillow, and it sucks the too often sour mixture all day long, during which time it probably seldom gets even a breath of fresh air. Why, infants reared in this fashion may form the future industrial classes. They appear, shortly after they can walk, little old men and women, with pale, careworn faces, narrow shoulders, and big, rickety joints. They enter the race of industrial life, in fact, more than heavily handicapped. Can we blame the work in such cases, when it is the fault of their parents that factory operatives are what we often see them? The mortality among infants in our manufacturing centres is fearful—indeed, in Birmingham alone, according to a recent return, the death-rate of infants under a year old is 187 per 1,000, while in London it is only 159. The former high mortality is undoubtedly due to improper or insufficient food. The strongest of the weaklings survive, it is true, and may ultimately enjoy good health. But an easily vulnerable residuum remains, and whenever any epidemic breaks out, they have not stamina to resist attack, and consequently they are mown down. Bad air, faulty drains, hot, stifling workshops, constant exposure to cold and wet, and suchlike influences, spread suffering and death among this weakly section of the working class. Their better-constitutioned fellows, however, are not so easily affected by disease-begetting influences. It may be said that the primary condition of developing a healthy industrial class is the expenditure of greater and more intelligent care on the part of working women in rearing their infants. The lads and lasses of the factory districts must have a fair and proper education in such matters, and as good a physical development as possible to start life with. Then, even though special trades are irremediably unhealthy, yet, being at the outset of life health-clad, the workers, both male and female, can better resist the attacks of disease and death.

When we come to consider the case of adults, the vexed and confusing question of personal habits obtrudes itself. What of the home of the worker? Too often it is one of a narrow row of cottages, black, grimy, ill-lighted, and with no drainage at all, or, what is worse, with disjointed drains badly connected with a main sewer. There is no inducement held out to improve, still less to beautify, the place. Yet, how often, in spite of all these drawbacks, does one see a house in such a row bright and clean within, and neat and tidy without? As far as shape, size, and position are concerned, it is precisely like its neighbours. But in such a case, you generally find a neat housewife at the door, who stays at home doing nothing but busying herself with the bustling duties of the "house-mother," as the Germans have it, and who does not go out to work in the mill. If men break up their family circle by making their wives and children labour, in order to obtain higher wages, a curse rather than a blessing is often the result. There is no wife at home to give the operative a welcome, and one or both of them wind up the evening at the public-house bar, instead of at their own fireside. Here they get, if not the comforts of home, at least a certain tawdry imitation thereof, in the shape of light, warmth, brightness, and a cheery chat or gossip. If the mischief ended here, not much harm might be done. But then it does not end here. These unfortunate people often take more drink than is good for them, and the bad results to their physical health are so familiar as to need no description. The effect of excessive indulgence in alcohol on the health of people generally is pernicious in the extreme. Much more disastrous are these effects where ill-cooked food is provided for the

hard-worked toiler by a slovenly wife in an unhealthy home. But when we admit that a certain proportion of the industrial classes are from their personal habits rendered liable to disease, we must eliminate this factor in studying the causes of disease in industrial occupations.

That the industrial classes are, as a body, increasingly drunken is questionable. No doubt, so many thousand gallons of alcoholic liquor more are consumed this year than last, and will be next year as compared with this one. But then so many thousand more pounds of meat are eaten every year now than used to be consumed in past times, when animal food was the rare Sunday treat of a working man's family. The truth is, that working people "live better," or, dropping the popular phrase, we may say more freely and luxuriously, nowadays than formerly. They take, as a rule, more healthy exercise, their appetites are keener, they have higher wages, they are better able to buy and have better powers of digesting more meat and drink than the last generation of operatives possessed. There are "atrocities" which arise from drunkenness in agricultural villages as well as in manufacturing towns, and it is utterly impossible to use as an argument the ratio of crime to drink. If crime is caused chiefly by drink, as is so often insisted, and if drinking is on the increase, how comes it that we have a record of diminishing crime from almost every great city in the country? Either the police reports are false, or crime is not mainly caused by drink, or the industrial classes are not drinking as much as is fancied. We are inclined to think, therefore, that the alleged dissipated habits of the adults of the working classes at the present day are not the chief factors in the production of any special ill-health which is found amongst them.

When people tell us that the human frame is a mechanism, they forget it is a mechanism of the chronometer order. It is self-adjusting, and if exposed to excessive strain will, nevertheless, tend to recover the balance. If, however, the constitution is *ab initio* faulty, the destructive influence of nature—which seeks to put every man into his coffin as quickly and unpleasantly as possible—attacks weak points in the armour of health. Bad liquor, acting on excitable nervous systems, is of course a demon which steals away men's health as well as their brains. But that it does so in the workman more than in his master is more than doubtful. To sum up, then, we believe that, given sound health in early life, and an intelligent observance of the ordinary laws of nature, the adult industrial operative of to-day is not, as a rule, more likely to suffer from disease than any other human being who works hard for his daily bread. This may appear a somewhat sweeping statement. But our recent system of compulsory sanitary legislation is developing healthy habits, and these habits are becoming sanitary instincts, so to speak, among the working classes. When it is considered that we are dealing with the children of a former sickly and neglected industrial generation, a certain amount of specific disease, dependent on feeble vitality as much as on unhealthy occupations, must of course be expected amongst them. In all trades, people are liable to risks of some sort or other, but what we wish to make plain is, that when physical vigour is present in the handicraftsman at the start, these risks, in so far as they affect health, are reduced to a minimum. In fact, the idle habits and amusements developed during strikes or "slack times" are more fraught with peril than constant hard work. Inventors arise without number when appliances for preventing trade diseases are required, and it only needs a little pressure on the part of the legislature to procure the application of the fittest improvement. Sick clubs and benefit societies are opening their eyes to their financial condition, and they will not care to have on their lists men engaged in unhealthy trades. To act otherwise means a heavy drain on the funds. These remarks may to many seem a bright view of a picture too often painted in the sombrest colours. We are, however, just now not dealing with a history of the past, which is perhaps gloomy enough, but describing the cheerfuller facts and tendencies of a wholesomer and more enlightened state of society. A wider conception amongst the masses of the laws of health and disease is eliminating many maladies from the catalogue of human woes, and in no case is this more marked than in making out a list of industrial sicknesses. That list shows more blanks year by year; and if British manufactures go on flourishing, all those employed in them may one day, without even exception, possess sound minds in sound bodies.

HEMP, FLAX, AND JUTE.—I.

ROPE SPINNING.

By David Bremner, Author of "The Industries of Scotland."

ROPE MAKING has within recent years undergone a great change. Formerly, it was a trade carried on in a small way, by many manufacturers, with the aid of a few primitive appliances; now it is for the most part concentrated in factories furnished with machinery capable of superseding hand labour to a large extent. For the purpose of illustrating the change that has taken place, and showing what machinery may do for a trade, we shall ask the reader to accompany us on a visit to some great establishment—such, for example, as that of Messrs. Frost Brothers, at Shadwell, probably the largest rope factory in existence. When this firm was founded, about ninety years ago, operations were conducted on a small scale, and then, and for a considerable time afterwards, only hand machines were used in the various processes. In those bygone days, hemp was thought to be such a coarse and refractory fibre, that when machinery was applied to the manufacture of cotton and flax, the workers in hemp congratulated themselves on their superior fortune. Wrapt in a "fool's paradise," they cherished the fond delusion that hemp was unassailable by mechanical agents, and they felt certain that however hand labour might be superseded in other trades, theirs at least was secure from any such disturbance. It was only natural, however, that mechanicians who had seen one kind of fibre after another yield to their ingenuity should entertain a determination to conquer hemp; and conquer it they did, though they found it rather troublesome stuff to deal with. Great employers of labour, like the Frosts, promptly availed themselves of the improved appliances as they were produced, never hesitating to discard an old machine when a new one could be found to do the work better. The consequence is, that in the various departments of the great factory at Shadwell they have to-day at work the very latest and most perfect mechanical appliances that have been devised.

The works to which we refer as illustrating practically the processes of rope spinning cover a strip of ground about a quarter of a mile in length, and seven acres in extent. They consist for the most part of two-storey buildings, and in following the raw material through the successive processes, let us visit the hemp stores first. Here are piled huge masses of hemp in bales and bundles. The varieties used are Russian, Italian, and Manila; of the latter an enormous quantity is always on hand, as a specialty of the firm is the manufacture of Manila rope. The Russian hemp is received in bales about half a ton in weight, the fibre being made up in "heads" or bundles of 14 lb. each. The Manila hemp comes in compact bales of $2\frac{1}{2}$ cwt., neatly covered with matting. On opening one of the latter, it is seen that the long and beautiful fibre is put up in the form of bundles not thicker than one's finger, and knotted at the end. This arrangement is troublesome for the manufacturers, as before the fibre can be dealt with all the knots have to be untied—an operation which here provides employment for a large number of young women. For some purposes, it is desirable that Russian and Italian hemp should be hackled—that is, combed out by being drawn over rows of steel spikes—and spun by hand. The hackling shop is furnished with sloping benches, on which several sets of hackles of various degrees of fineness are arranged. Taking up a bundle of hemp, the workman strikes it upon the hackles, and by drawing and shaking it in a peculiar way extracts the tow, or short and weak fibres. The operation is repeated—first on the coarser and then on the finer hackles—till the desired degree of fineness has been imparted to the fibres. This occupation is a laborious one, and those engaged in it have inevitably to inhale great quantities of dust. The hand-spinning room, to which the hemp is next removed, is remarkable for its length—1,000 feet. It is just such a place as Longfellow describes:—

> "In that building long and low,
> With its windows all a-row,
> Like the port-holes of a hulk,
> Human spiders spin and spin;
> Backward down their threads so thin
> Dropping each a hempen bulk."

A series of large, broad-rimmed wheels, arranged at either end of the room, give motion to sets of spindles, and on to one of those spindles the spinner casts a loop of hemp, which he pulls from the huge bundle wrapped round his waist. Walking backwards, he draws out a thread of any required thickness, the spindle twisting the fibres firmly together as he pays them out with both hands. The forefinger and thumb of his right hand are his only guides as to the weight of yarn he is making, and long experience enables him to produce a succession

The Spinning Room in the Shadwell Rope Works.

of threads many yards in length, which shall not vary one from another in weight to the extent of any appreciable fraction of an ounce. Having completed his backward walk to the end of the room, the spinner casts a fresh thread upon the wheel that is there in operation, and so he goes on from morn till night pursuing his rather monotonous journeys. A fairly expert spinner will convert in a day of ten and a half hours about 84lb. of hemp into 14,000 yards of yarn, for which work he receives 6s. Before being twisted into rope, the yarn has to receive a bath of tar, for the purpose of preserving the hemp. For this purpose, it is wound in "hauls" of 280 threads each, upon a large revolving frame of awkward appearance, and bearing the equally ungainly name of a "whim-wham." From this point, the hand-spun and machine-spun yarns are similarly treated, and it is now necessary to inspect the operations conducted in the machine-spinning department.

Let us begin with the motive power. That consists of three steam engines, having a combined energy of from 300 to 400 horse-power. One of the engines is specially worthy of notice, as it was made and fitted up by Messrs. Boulton and Watt, in 1811. Its working parts are highly finished, and the makers put it forth as a sample of their highest quality. Though only 60 horse-power, the machine requires a large room for its accommodation, the beam being fully 20 feet in length, and the fly-wheel about the same in diameter. Near it is a 250 horse-power engine on the horizontal principle, which looks a mere dwarf in comparison. A third engine is solely devoted to driving the great endless-rope-making machine, of which we shall have something to say further on.

The hackling and drawing room is the first of the machine-spinning series. In it are a number of strongly-constructed machines, which make a hideous noise, and set a deal of dust flying, but which are capable of getting through a great amount of work. The Manila fibre is fed in as it comes from the stores after being freed of knots, and is speedily converted into a fine even "sliver." While passing through the first hackling machine, it has a quantity of oil sprinkled over it, to increase the pliability of the fibres. Some American hackling machines of very ingenious construction are employed for treating Russian and Italian hemp, a special feature of their construction being a capability of adjustment so as to extract any required proportion of tow. The slivers are hoisted to the spinning room—a large, lofty apartment crowded with machines of various kinds, where they are twisted into yarns. Some of the spinning machines are of American make, and form the yarn by an arrangement which imparts to the mechanism something akin to instinct. The sliver is fed into these over a fine travelling hackle, and then passes through an "eye" in an upright brass tube, in which, by an arrangement of springs and weights, the hemp as it moves forward is subjected to a regulating process identical to that which is exercised by the finger and thumb of the hand spinner. If the hemp threatens to pass in too quickly, the feed motion is retarded; and if it should be too thin at parts, the feed motion is quickened; and all this with a certainty that even the human hand could not equal. The result is that a yarn of unusual evenness is produced in the simplest possible manner, and at a speed far exceeding the capability of the hand spinner. The yarns are made in a great variety of sizes, as the products of the factory vary from fishing-net twine to cables 20 inches, or even more, in circumference. The contrast between this room, with its fast-whirling, compact, and beautiful machines, and the hand-spinning room, where the "human spiders" plod slowly backwards and forwards to the "drowsy, dreamy sound" of their wheels, is very striking, and it is hard to believe that the objects which are being accomplished in both are identical.

The smaller kinds of Manila rope are made on what are called "endless machines," another American invention. Bobbins containing the yarn are placed horizontally in the machine, and these are twisted into strands, and the strands into rope, by simultaneous operations. The rope made in this way is remarkably even and firm, and as each machine is capable of turning out about 300 yards an hour, and one man can attend to several machines, a great saving of labour is effected. Lines and twines are made on perpendicular machines of somewhat similar construction. All the ropes made of Russian and Italian hemp are tarred, in order to preserve them. In the case of Manila, tarring is only required when the rope is to be subjected to much immersion. The tarring shop is, as a precaution against fire, detached from the other buildings. To it the yarns are brought in the form of hauls, already referred to. Sunk in the floor of the shop is a large tank filled with tar, which is kept at a temperature slightly under boiling point. Behind the tank, and fixed in a wall which separates the shop into two compartments, is an aperture fitted with a compressor. Through this aperture

the end of the haul of yarn, after being dipped in the tar, is passed, and put in connection with a steam capstan, which draws it off as it is tarred. The yarn is fed into the tank in an even, steady manner by a workman, and as it leaves the capstan in the next room it is arranged in coils by another operative. The yarn is so tightly wrung by the compressor that it may be grasped without soiling the hands. It is next placed on the whim-whams, whence it is wound upon bobbins for the strand-forming machines.

In the "laying ground," which portion occupies the ground-floor beneath the spinning rooms, are located the strand-forming and laying machines and their appurtenances. The machines are placed on rails about $2\frac{1}{2}$ feet apart, and as there are fourteen double lines extending from end to end of the building, the aggregate length of railway is $3\frac{1}{2}$ miles. A number of bobbins, corresponding with the number of yarns to be used in making a rope of any required dimensions, are placed in a frame, so that they may rotate clear of each other; and the yarn, in three divisions, corresponding to the number of strands in the rope, is led thence to a beam in which three tubes are fixed. The yarn intended to form the several strands is passed through the tubes, and attached to the spindles of the forming machine. The latter is then set in motion, and as it moves off along its line of rails, it draws the yarn through the tubes and twists it firmly. This is an important operation, as on the care with which it is performed depends whether the various yarns are so disposed as to bear an equal part of the strains to which the completed rope may be subjected. As the strength of a chain is determined by what the weakest link will bear, so the strength of a rope depends on the extent to which the individual yarns do their work. The strands made from tarred hemp-yarn become, under the twisting process and the burnishing action of the tube, almost as hard and smooth as rods of turned wood. As the strands are formed, they are supported on pendent hooks to wait the next operation, "laying"—that is, twisting into the form of a rope. One end of each of the three strands is transferred to the spindles of a stationary machine, and the other ends are brought together and attached to one spindle on a travelling machine. The machines are set in motion simultaneously, and as one gives to the individual strands some additional twisting, the other twists the strands together and completes the rope. In order to ensure an even twist, the strands are held apart at a point close in front of the laying machine by a conical block of wood with three longitudinal grooves in its circumference. All that now remains to be done is to wind up the rope in a compact coil, ticket it, and pass it to the warehouse. Only the heavier ropes are made singly, all the strand-making and laying machines being capable of dealing with two ropes at a time.

By the processes described the lengths of rope usually in demand are produced; but, as in the case of lines and small ropes, Messrs. Frost Brothers have appliances for producing "endless ropes"—that is, ropes of indefinite length—of the largest diameter. The great endless-rope-making machine occupies a room by itself, but so compact is it that it does not cover a floor-space of more than a dozen feet square. In a well under the machine is a tall, circular bobbin frame, capable of holding sufficient bobbins to supply yarn for a 10-inch rope. Over this frame is a strong system of wheels and twisting gear. The yarn is led upwards through tubes, and formed into strands, and these travel only a few inches, when they are twisted into a completed rope, which is wound off on a reel beside the machine. As already stated, there is no limit to the length of rope that may be produced by this machine; so far, its greatest achievement has been the making of a Manila $6\frac{1}{2}$-inch rope 10,000 fathoms in length, to be used in grappling for telegraph cables. The weight of this monster cable was over 40 tons.

A peep into the warehouse gives us some idea of the variety of demands made upon the rope maker. Here are huge cables for mooring vessels of the largest size, tarred Manila rope for trawling purposes, all sizes of cordage for rigging, clothes-line, net-twine, soft rope for piston-packing, and so on; nor should we overlook the sample of cable made specially for the rope-walker, Blondin. One piece of rope is so like another that once a bit disappears from a ship or boat there is difficulty in identifying it, and hence a sort of premium is offered to thieves. To provide against such contingencies, Messrs. Frost Brothers adopt a most ingenious device. They have the name of their own firm, and the names of the customers for whom they make specially, printed on a narrow tape, and this is worked into the body of the rope so that it cannot be extracted, and all that is necessary when the identification of a rope is in question is to undo a piece of it and reveal the tape, against which no other evidence can avail.

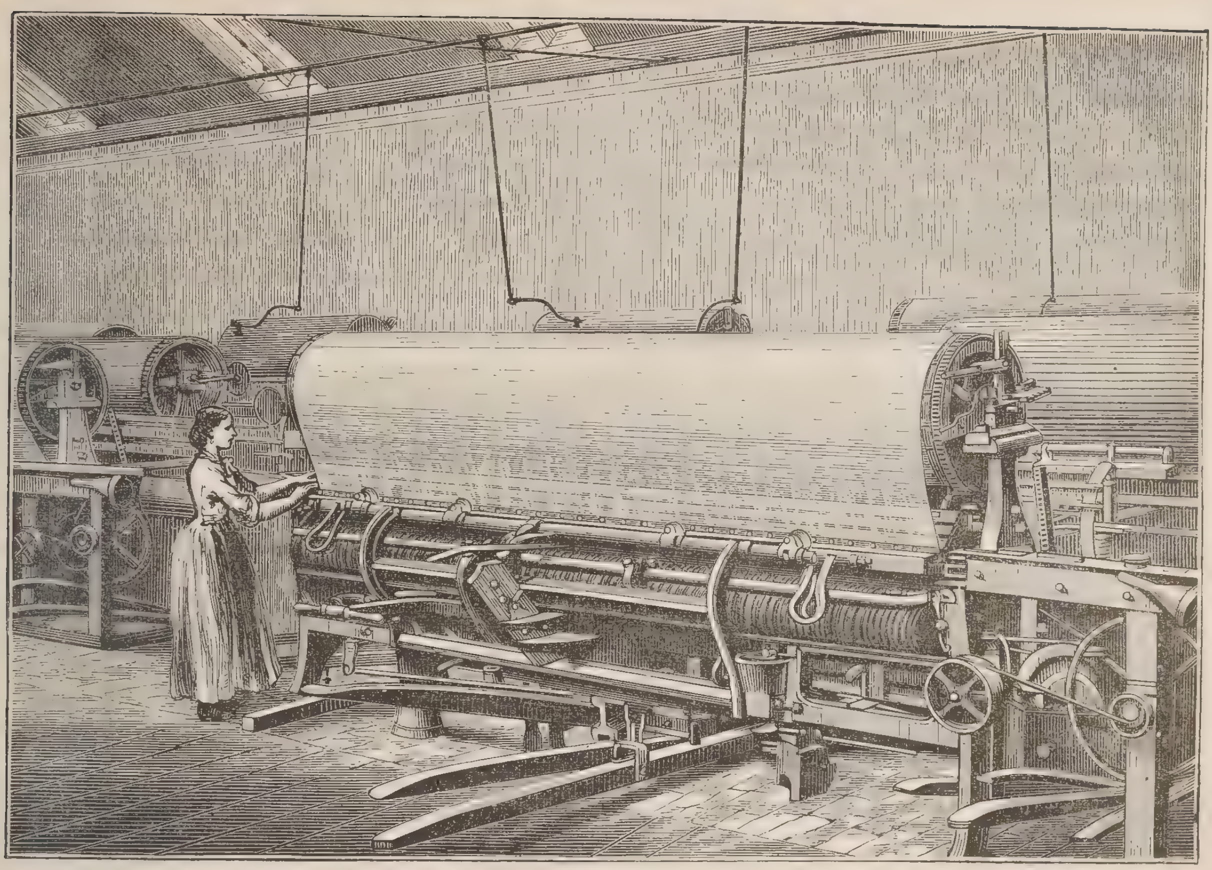
In order to witness the conversion of hemp into

other articles, such as sail-cloth, sacking, and fishing nets, we must go elsewhere, as Messrs. Frost Brothers confine their attention to the production of ropes, lines, and twine. It is long since hemp was applied to the manufacture of sail-cloth, its strength and durability having recommended it as being specially suited to that purpose. Only the finer qualities are used, and it is worked on machinery adapted from that devised for dealing with cotton wool. There are several extensive makers of canvas in England, and besides supplying our own requirements, which are the greatest of any nation in the world, our manufacturers export yearly to other countries not less than five million yards, worth about £300,000. Of sacking, made from the coarser fibres of hemp, flax, jute, &c., our exports amount to the value of nearly £2,000,000 a year. With regard to cordage and twine, our exports and imports nearly balance each other, the advantage being slightly in favour of the latter.

Were it not that several substitutes for hemp in the manufacture of cordage have been introduced in recent years, our consumption of that fibre would now be enormous. Iron, which has invaded the province of so many other materials used in the arts, is one of the chief competitors with hemp, being now extensively employed in the making of ropes. In the heavier parts of ships' rigging, for haulage in mines, and many other purposes, it has almost entirely superseded hemp. A first-rate man-of-war of the old school required sixty or seventy tons of hemp rope for her equipment; now a fraction of that quantity is sufficient for the largest ironclad. Hence it is that while, so far back as 1790, we imported 592,306 cwt. of hemp per year, we now take little more than double that quantity, though our shipping has increased to many times the tonnage we then owned. The use of iron as a substitute for hemp originated about forty years ago, with Mr. G. W. Binks, of Poplar, then foreman rope maker at Woolwich Dockyard. Owing to various causes, hemp had become very scarce and dear, the price at one time reaching £4 per cwt. This led to experiments being made with the view of discovering some fibre that would take the place of hemp, and render us independent of the vicissitudes to which the hemp growers of Russia were subject. Mr. Binks procured some fine iron wire, and tested its utility in the form of a cord. He was surprised at the strength displayed by this baby iron rope, and submitted specimens to the Admiralty. The officials in that department pooh-poohed the idea of rigging a ship with iron, and Mr. Binks met with no encouragement at their hands. A captain on board one of Her Majesty's ships came to Mr. Binks's aid, however, and enabled him to establish a small wire-rope manufactory at Grimsby. This was in 1835, and it was a considerable time later than that before the invention was fully appreciated. Now there are nearly as many manufactories in the country for making wire rope as there are for making ropes of hemp, and the uses of their products are almost innumerable. Cords made of copper and brass wire have also taken the place of hemp for certain purposes. Besides supplying an extensive and rapidly increasing home demand, our wire-rope makers export to the value of about a million sterling per annum.

It may be useful to state here the comparative strength of various kinds of rope. From the report of a discussion on rope making which took place at a meeting of the Institute of Mechanical Engineers, at Birmingham, we glean the following data:—Taking the breaking-weight of a rope of Russian hemp to be 100, that of an Italian hemp rope would be represented by 107, and that of a Manila rope by 73. Tarred ropes are weaker than untarred, because the tar affects the fibre. An iron-wire rope $1\frac{1}{10}$ inch in diameter broke with a weight of $18\frac{1}{2}$ tons; a hemp rope to stand the same test would require to be 3 inches in diameter, the latter weighing 16lb. to the fathom, and the former only 10lb. A steel-wire rope is 50 per cent. stronger than an iron one of the same dimensions. An objection to ropes of either metal is that they are apt to crystallise and give way after an indefinite period of use. Some experiments made at Liverpool gave the following results, which place Manila hemp in a better position:—A $3\frac{3}{4}$ inch galvanised wire rope broke with a weight of 29 tons 15 cwt. A Manila rope of the same size snapped at 5 tons 17 cwt., and one of Russian hemp at 4 tons 15 cwt. In the trade, a Manila rope is generally reckoned to be about 40 per cent. stronger than one of Russian hemp. This gives a great preponderance in favour of iron rope as regards strength; and when we consider its lightness, durability, and cheapness as well, it becomes easy to understand its extensive popularity.

The manufacture of canvas and cordage from hemp is carried on in about forty factories in the United Kingdom, and in numerous small establishments that do not come under that designation. In the factories there is spinning machinery to the extent of 40,000 spindles, and the operatives number between three and four thousand.



Net Loom in the Stuarts' Factory.

HEMP, FLAX, AND JUTE.—II.

THE MANUFACTURE OF FISHING NETS—HEMP CULTIVATION—VARIOUS CORDAGE FIBRES.

By David Bremner, Author of "The Industries of Scotland."

A LARGE quantity of hemp is used in the manufacture of fishing nets—a branch of industry for which Bridport has long been famous. In that town eleven firms are engaged in the business, some of whom do an extensive trade for both home requirements and export. The Pelican Twine and Net Works, belonging to Herbert E. Hounsell (limited), is perhaps the best-known manufactory of the kind in the kingdom, having been established over two hundred years. In some other towns in England, and also in Scotland and Ireland, net making is carried on, but not to the same extent as at Bridport. In the Scotch herring fishery cotton nets have largely superseded those made of hemp, but hemp is still the material in favour with the people engaged in the Canadian and adjacent fisheries. Salmon, mackerel, and pilchard nets are almost exclusively made of hemp; while the French sardine fishers give the preference to flax.

Messrs. J. & W. Stuart, of Musselburgh, near Edinburgh, are the proprietors of the earliest and most extensive net manufactory in Scotland. They succeeded in business Mr. James Paterson, the inventor of the net loom. The history of this invention is worth relating. Paterson was employed in early life as a cooper; and as he strolled about the links in the evenings, and gossiped with the young women who sat in groups busily making nets for their fathers or brothers, it occurred to him that a machine might be constructed to relieve his fair friends from their tedious task. He watched for hours at a time how the meshes were regulated, and the knots formed; but his ideas had not taken practical shape before he joined the army and went off to the wars. He soon made a good position for himself, and as deputy-assistant commissary-general served in Egypt, the Peninsula, and Waterloo. Circumstances were not favourable for his doing anything to realise his notion for the improvement of one of the arts of peace; but "when wild war's deadly blast was blawn," and he returned to his native place, he resumed consideration of the subject, which he used to declare was, even in his sorest straits on the battle-field, ever present to his mind.

Taking into his confidence an ingenious mechanic, he set to work, and after much anxious toil and many disappointing failures, completed a machine which he believed would answer the purpose he had in view. Everything being adjusted, the levers were put in motion, and success seemed achieved, when, after one or two movements, the mechanism came to a dead halt, and could not by any available means be got to move again. Hours were spent in attempting to discover what was wrong, but without success, and, wearied with his prolonged anxieties, Mr. Paterson resolved to abandon all hope of seeing a net woven by machinery. Flinging the key of the room to his colleague, he went home. The mechanic induced a friend to examine the machine with him, when they found that the stoppage was caused by a bolt slipping from its place. The defect was made good, and the machine was got to work smoothly. Mr. Paterson, who was by this time in bed, was called, the fact that the machine was "all right" reported to him, and when he went to look at it, his assistant was producing by its aid row after row of meshes at a rate which a score of hand workers could not equal.

The net loom has since been improved in various details, but its principle of action is identical with that displayed in Paterson's pioneer apparatus. The machine, though called a loom, may be more accurately described as a hybrid between a loom and a knitting frame. It is about eight feet in length, and six feet high. The lower part consists of a series of levers or pedals which give motion in succession to the hooks, needles, and sinkers, which are arranged in a horizontal line about three feet from the floor. Over all this is a drum on which the work is wound as it is produced. The machine is worked in this way:—The operative—usually an active young woman—moves a lever which draws the last-completed row of meshes off the sinkers, and transfers them to the hooks. Another lever is moved, and the meshes are caught by the needles. The effect of these changes and the movements of other parts of the machine is to twist the lower part of each mesh into a loose knot. The foot of the operative presses another lever, and a steel wire is thrust across the machine through all the knots. There is a hook at the end of this wire—or shuttle, as it is called—into which the end of a piece of twine is fixed. The wire is then withdrawn, and, as it goes, takes the twine along with it. Now the sinkers play their part. They consist of thin slips of brass, having a hook or notch formed on the upper end, and are situated between the needles. When the twine has been drawn across through the loops of the meshes, the sinkers are released in succession, and, as they descend, each draws down the cross thread into a loop, sufficient to form two sides of a mesh, the other two sides being formed of the same parts of the previous row. Another movement or two remove the knots from the needles and draw them firmly, thus completing the operation. The occupation of the net weaver is rather an arduous one, as in the formation of each row of meshes half a dozen levers have to be pressed with the foot, and a journey has to be made from one side of the machine to the other. In working the larger looms steam power is employed.

The botanical name of the hemp-plant is *Cannabis sativa*. It is supposed to be a native of the warmer parts of Asia, but for many years it has been naturalised in Europe, especially in Russia, Italy, and Austria. Its cultivation has also been extended to America, and some small patches of land have been devoted to it in England. In Bengal the plant has been cultivated from time immemorial, not for its fibre, but on account of its yielding the resinous basis of the intoxicating beverage called *banga* or *bhang*. The Egyptians, Arabians, and other Eastern peoples, have also regarded this as its most valuable property. The liquor derived from hemp is known among the Arabs by terms signifying "the increaser of pleasure," and "the cementer of friendship;" while in Syria and the neighbouring countries it goes by the name of *hasheesh*. It is stated by Herodotus that the Thracians were familiar with the value of hemp fibre, and that they made cloth of it which none but a very experienced person could distinguish from cloth made of flax. More than two centuries before Christ the ships of Syracuse were rigged with ropes made of hemp grown in the valley of the Rhone; and Pliny tells us that towards the end of the first century the fibre was in common use among the Romans for sails and cordage.

Our supplies of hemp are drawn chiefly from Russia and Italy. The modes of cultivation differ somewhat in the two countries; but it will suffice for our purpose to give a brief outline of how the plant is at present reared in Italy. In the district of Bologna and Ferrara, in the province of L'Emilia, the growth of hemp has been carried to a high degree of perfection. The rotation of crops followed on the best land is—(1) hemp; (2) maize, barley, or oats; (3) wheat; (4) hemp; and so on. The soil has to be prepared with great care, and thoroughly manured. After being ploughed deeply.

it is pulverised with mallets until the surface is as fine and even as a garden-plot. Sowing takes place in March, and much depends upon the choice of seed and the proportion used for various kinds of land. It is usual in the case of maize and corn to sow thinly on the rich soil; with hemp the course followed is exactly opposite; for this reason—that if the plants were not close on the rich ground they would grow large and coarse, whereas the more valuable fibre is obtained from the more slender stalks. The seed is sown with a machine, and raked in. The plant appears above ground in ten or twelve days, and then the farmer has to contend with the vicissitudes of weather, insects, and diseases. A species of caterpillar infests the finer stalks, and if it is allowed to carry on its operations for a short time the stalks perish. Fortunately the caterpillar has a powerful enemy in the shape of an insect which destroys its eggs and thus checks its reproduction. Of the diseases to which the plant is subject, the two which do most mischief are—pallor, which arises from a want of iron in the soil; and rickets, or drying up of the stalk and leaves. The male plants are reaped first, the female ones being left and allowed to develop their seed-vessels. When all have been cut down, the steeping process begins, its object being to separate the fibrous from the woody part of the stalks. In its simplest form, a macerating basin is made by embanking a section of an open ditch; but this answers very imperfectly, as mud is certain to find its way among the hemp. An improvement on this mode is the construction of substantial stone basins or tanks, which are filled with clear water, into which the bundles of hemp are thrown, and arranged, and trodden down by peasants. The work is disagreeable, and when the water stagnates malaria is engendered. In Sicily a greatly improved *maceratojo* has been introduced as an independent speculation. At a distance from any human habitation, a large number of basins of great capacity have been constructed of stone and cement, in the most substantial manner; into these, while empty, the hemp is arranged, and then the water is allowed to flow in. The water can be changed as often as necessary, and the work may be carried on with comparative health and comfort. The time the hemp is left in the macerator depends upon a variety of circumstances. On being taken out it is placed in heaps to dry. It is next beaten with wooden mallets to separate the fibre, and then the stalks are drawn separately through a brake, which completes the detachment. By the application of a strong brush the loose bits of the husks are removed, and the fibre is ready for the market.

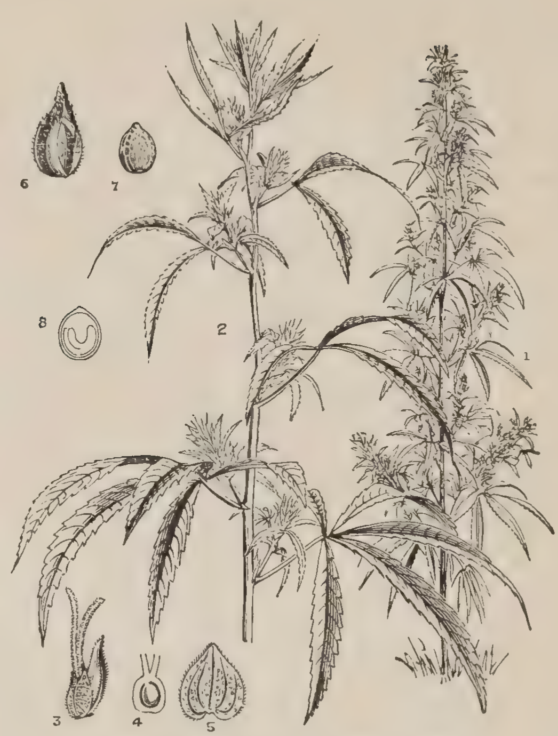
The macerating process requires so much time, and is so disagreeable, that many attempts have been made to dispense with it, by devising machinery capable of effecting the separation of the fibre. So early as 1816 a machine was produced which performed the work after a fashion, but owing to the glutinous matter in the plant, the fibres were left in a sticky condition, which much retarded the subsequent processes of preparing and spinning. By various hands improvements were effected in the mechanism, and now a considerable quantity of hemp is prepared without maceration; but it is considered to be much inferior in quality to that treated in the old-fashioned style. While mechanicians have been devoting their attention to the production of machines to obviate maceration, chemists have been trying to find means whereby the latter process might be made more expeditious and less offensive. So far, it cannot be said that complete success has been achieved by either: but the problem will no doubt be solved some day.

In order to induce the lazy peasants to work, the Italian hemp farmer has to adopt a peculiar mode of payment, known as the *metayer* system. He arranges with a family or gang of workers to accomplish certain parts of the work of cultivation, in payment for which they receive one-third of the produce and certain perquisites. The farmer ploughs the land and sows the seed, and the peasants break the clods, drive off birds, pull the weeds, cut down the crop, carry it to the macerators, and, finally, beat the stalks and separate the fibres.

But the *Cannabis sativa* is not the only plant from which cordage fibres are derived. It has a rival in the wild plantain (*Musa textilis*) of the Philippine Islands, which yields the strong and beautiful fibre known as Manila hemp. In America this variety of hemp is used very extensively, and it is increasing in favour in this country. In 1831 our imports were only 2,262 cwt.; now we take about 400,000 cwt. per annum, at a value approaching £600,000. To meet this demand the natives have devoted themselves to extending the cultivation of the plantain, and now it covers extensive tracts of ground in the principal islands. In the localities to which the plant was indigenous, the people appear to have long been acquainted with its value as furnishing material for clothing, rope making, and the like. Dampier, in the narrative of his voyage in the Indian Archipelago, gives the following description of the preparation of the fibre

Male Hemp Plant (*Cannabis sativa*).

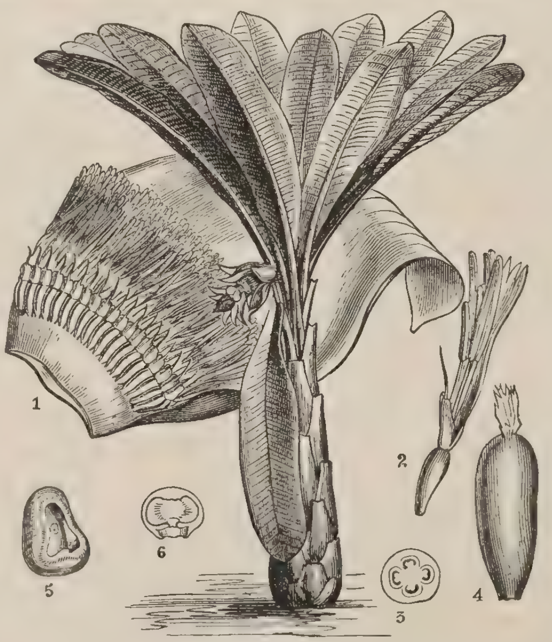
(1) Plant, 6 feet high; (2) Portion of the Main Stem, showing Leaf and Panicle of Male Flowers, half nat. size; (3) Unopened Bud, nat. size; (4) Fully-expanded Male Flower, showing Pendulous Anthers; (5) Views of the Stamen.



Female Hemp Plant (*Cannabis sativa*).

(1) Plant, about 7 feet high, in Fruit; (2) Terminal Portion of Female Plant, in Flower, one-third nat. size; (3) A Female Flower, much enlarged; (4) Section of Ovary, much enlarged; (5) Perianth unrolled, much enlarged; (6) Fruit surrounded with the persistent Perianth, 1½ times nat. size; (7) Seed, 1½ times nat. size; (8) Section of Seed, 1½ times nat. size.

by the natives:—"They take the body of the tree, clean it of its outward bark and leaves, cut it into four quarters, which put into the sun, the moisture exhales; they then take hold of the threads at the ends and draw them out; they are as big as brown thread; of this they make cloth in Mindanao, called *sazgen*, which is stubborn when new, wears out soon, and when wet it is shiny." The present mode of treating the fibre is almost the same. When the trees begin to throw out their fruit-branches they are cut down close to the ground, the leaves and branches removed, the outer part of the stems stripped off until the fibres are reached, the stems laid open and placed in the sun to dry. When sufficiently dried, the stems are laid on the ground, and the fibre is pulled out in belt-like pieces three or four inches wide. Some pulp clings to the fibres, and this is removed by drawing them under a knife pressed against a board. Each bundle of the hemp is about as thick as one's thumb, and in order to facilitate the handling of it a knot is put on one end, and allowed to remain until it is removed by the rope makers of the countries to which it is sent.



Wild Plantain (*Musa textilis*), 30 feet high.

(1) A Bract with several rows of Flowers; (2) A Flower, one-third nat. size; (3) Horizontal Section of Ovary; (4) Ripe Fruit, one-third nat. size; (5) Seed seen from the under side, showing the hilum, one-half nat. size; (6) Horizontal Section of Seed.

New Zealand flax *(Phormium tenax)* is being extensively used in the colony, and also in Australia, for the manufacture of cordage, wool-bags, and mats. In appearance this plant resembles the flag or sedge, and is indigenous to New Zealand, where it is to be met with abundantly in marshy situations, and also on the sea-coast. The fibre, which is detached with some difficulty, owing to its being enclosed in a resinous coating, bears some

resemblance to jute, but it is harder and also stronger. Successful experiments have been made in the cultivation of the *Phormium tenax* in Britain and various other parts of Europe, and the promoters of the scheme for the development of the Mississippi valley have contemplated the introduction of the plant to that region, where it is believed it would thrive well. Owing to the extent to which the fibre is now worked in the colony, New Zealand has almost entirely disappeared from the list of importers of cordage, and her exports of that commodity and flax have assumed important dimensions, amounting in the aggregate to not less than £200,000 a year in value. The colonists have found the flax a remunerative crop, and are devoting considerable attention to it. In all the centres of population flax factories have been established, and these, and the cultivation and gathering of the crop, give employment to a large number of persons. The price of the dressed flax ranges from £20 to £36 per ton, according to the quality. A few years ago a series of experiments were made at Wellington to test the durability of New Zealand flax rope as compared with rope made from Manila hemp. These showed that the former withstood wear 34 per cent. better than the latter, though it was more liable to chafe, and more susceptible to weather influences. The advantage was, however, reversed when the ropes were saturated with sea-water, in which case the Manila rope showed

Agave (*Agave sisilana*).

(1) Plant, one-thirtieth nat. size; (2) A Branch of Flowers, quarter nat. size; (3) A Leaf, one-tenth nat. size.

New Zealand Flax (*Phormium tenax*).

(1) Plant, 7 feet high; (2) Branch of Inflorescence with young Fruit, one-third nat. size; (3) Corolla of Flower, cut open, showing Ovary, one-third nat. size; (4) Section of Fruit, showing imbricated Seeds.

Rheea Plant (*Urtica tenacissima*).

(1) Terminal Portion, one-third nat. size, showing Female Flowers in the axils of the upper leaves, Male in the lower ones; (2) Cluster of Female Flowers, three times nat. size; (3) Female Flower, six times nat. size, and (4) Section of same; (5) Male Flower, six times nat. size.

itself to be better than the New Zealand by 10 per cent.

Another important material used in the manufacture of cordage, matting, &c., is coir, as the fibrous rind of the cocoa-nut is called. Of this article we import about 10,000 tons per year, at a cost of over £200,000. It comes to us chiefly in the form of yarn suitable for making cables, and as thus employed the fibre is held in high esteem on account of its strength, lightness, and elasticity. Vessels furnished with coir cables have, in many instances, ridden out storms in which others, though moored with heavier ropes of common hemp, have come to grief. For many purposes in which strength is a more important factor than elegant appearance, coir is used with much advantage, such as in netting for sheepfolds, &c., mats and bags for seed-crushing machines, nose-bags for horses, brooms and door-mats. Attempts have been made, and not without some measure of success, to reduce the fibre to a degree of fineness sufficient to admit of its being worked in the loom into various fabrics. Coir mat making has been introduced pretty extensively into our prisons, and as the labour of convicts is cheaper than free labour, great dissatisfaction has been created in the ranks of those engaged in the trade outside prison walls.

Various species of the agave plant supply a valuable fibre which is used for rope making and other purposes in Mexico and Peru, and has come into favour in the United States. England is also an importer to some extent. Sisal hemp is the product of the *Agave sisilana*, and the United States' rope makers draw large supplies of it from Yucatan. Successful experiments have also been made in introducing the plant into the States, Key West and the adjacent islands now growing a considerable quantity. When carefully prepared, sisal hemp brings a higher price than Manila hemp. The fibre is contained in the leaves of the plant, which are cut off at a certain period of growth. After being dried for a little time, they are beaten with a mallet to loosen the fibre. Before the fibre can be finally released, the gummy substance in the leaf has to be got rid of by steeping in water and a vigorous application of a wooden scraper. The steeping is sometimes carried on till fermentation sets in; but that process, though it facilitates the separation of the fibre from its glutinous case, greatly deteriorates its quality. It is said that ropes made of sisal are lighter, stronger, and more durable than those made of ordinary hemp.

Indian hemp, or sunn, is used for rope making in many parts of the East, but it is of poor quality, and has nothing but its cheapness to recommend it. A more important Indian fibre is that derived from the rheea plant. It is a species of nettle, and its fibre is superior to both flax and hemp. In gloss and fineness it resembles silk, and having besides somewhat of a woolly character, it is fitted to occupy a high place among industrial fibres. Experience has shown that it can be easily worked on worsted machinery, and in combination with either cotton or wool, and that in the form of cloth it is very strong and durable. For rope-making purposes, it is superior to hemp, as being stronger, and suffering less deterioration from being frequently wetted. Its lightness and durability fit it also for making sail cloths, tents, &c. As a basis in the manufacture of paper, it admits many materials otherwise unsuited for the purpose to be worked up. Under the name of China grass cloth, a fabric made from rheea fibre has long borne a high reputation. In 1803, Dr. Roxburgh named the plant *Urtica tenacissima*, and pointed out its importance as a yielder of fibre. At the Exhibition of 1851, it was brought into notice somewhat prominently, and ropes made of it were shown which possessed a strength equal to three times that of ropes of the same dimensions made of Russian hemp. The value of the fibre was generally admitted, but a serious obstacle to its introduction as a competitor with flax and hemp lay in the difficulty of its preparation. In 1869, the Indian Government offered a prize of £5,000 to the inventor of the best machine for separating the fibre from the stem, the conditions being that the cost of preparation should not exceed £15 per ton, and that the fibre produced should be of a quality to command a price of £50 per ton in the English market. It was also considered desirable that the fibre should be got out while the plants were in a green state, as then it presented a richer gloss; and as a supply of green stalks could not be had in this country, it was necessary that the machines should be tested in India. At the specified time only one machine was brought upon the ground, which, though very ingenious, failed to realise the conditions of the competition; it was, however, considered so meritorious that the makers were rewarded with £1,500. Subsequent attempts to deal with the plant have been attended with an encouraging amount of success, and it may indeed be confidently predicted that rheea will, ere long, take an important position among our industrial fibres.

SHIP BUILDING.—II.

THE ROYAL DOCKYARDS.

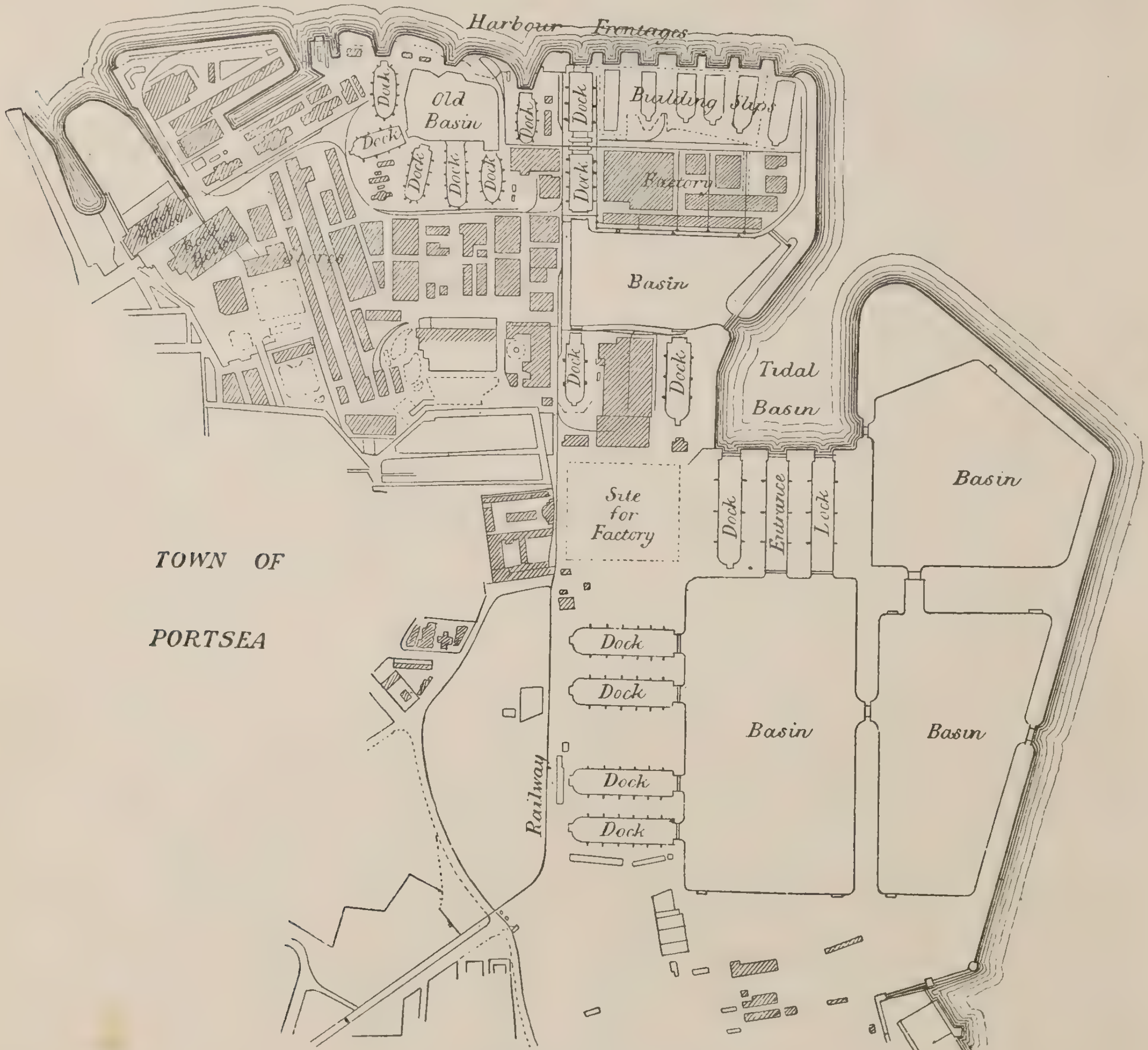
ROYAL dockyards are distinguished from the largest private ship yards by their antiquity and extent, as well as by their organisation and the diversity of their operations. They are really naval arsenals, comprehending all that is necessary for the building, equipment, and repair of our war fleet. As the types of war ships have changed, so have the dockyards been modified and extended to meet altered requirements; but much remains in them which is venerable on account of age or historical associations. In 1867, there were seven of these dockyards. Since then the yards at Woolwich and Deptford have been closed, and there now remain those at Portsmouth, Chatham, Devonport, Sheerness, and Pembroke. There is evidence that at so early a date as 1212 there was a naval establishment at Portsmouth; the sheriff of the county of Southampton having then received an order to enclose the king's docks by a strong wall, and to provide suitable storehouses. Until the reign of Henry VIII., however, there was no royal navy specially built for fighting, nor any royal dockyard worthy of the name; and to that monarch belongs the credit of founding yards at Portsmouth, Woolwich, and Deptford. Chatham yard was founded in the reign of Elizabeth; Sheerness yard was established about 1661, and re-modelled about 1823. Devonport yard dates from 1693; and Pembroke yard from 1815. More than 16,000 men are employed in the five existing dockyards, the annual wages exceeding a million pounds sterling. Nearly one-half of these men are permanently employed, and become entitled to pensions after ten years' service; the values of their pensions vary with the length of servitude, and on attaining the age of sixty all workmen are retired from active service. The hold thus obtained on the men has very beneficial effects: strikes or interruptions to steady work are unknown in the dockyards; a force of highly-trained artificers is always available, and this can be reinforced by large bodies of hired workmen in cases of emergency. It is probably within the truth to say that nowhere can a body of workmen be found superior in education, intelligence, and capability, to those employed in the royal dockyards. The Admiralty train a large part of this staff by the system of apprenticeship, but a large number of recruits come from private establishments.

Every class of workman required in connection with the building or repair of ships and engines is represented in the dockyards. Twenty years ago, wood ships alone were built in these yards; but now no wood ships are constructed, iron and composite ships having replaced them. A very large number of wood ships, however, remain on service, and their repairs constitute no mean share in the work of many of the yards. The leading trade is the *shipwright;* about one-fourth of the total number of men employed belong to this class. A shipwright in a royal dockyard is, however, a very different workman from one bearing the same name in a private yard. Minute sub-division of labour amongst different classes of workmen, such as exists in private establishments, is unknown in the dockyards: a shipwright is required to be able to work indifferently on wood and iron ships, performing for the latter the more difficult operations which the *plater* performs in private yards. The rougher parts of the iron shipwork are done by a class termed *skilled labourers,* who act as closers, drillers, riveters, caulkers, and painters, under the supervision of the shipwrights. Smiths, joiners, caulkers, riggers, sail makers, plumbers, fitters, founders, and members of other minor trades assist the shipwrights in completing the fittings of ships; but it is still as true as it was in the days of wood ships, that the shipwright builds our men-o'-war.

Except in special circumstances, the workmen in the dockyards are not employed on piece-work, or paid in proportion to the work accomplished. It is therefore necessary to have a well-organised system of inspection and supervision, in order to secure the proper quantity and quality of work; and such a system is in operation. The workmen are arranged in groups of twenty or thirty, and a subordinate officer is made responsible for the satisfactory performance of duty by each group; over these subordinate officers superior officers are placed, who direct particular sections of the work of the yard. Over these, again, come several chief or principal officers; and at the head of each dockyard a naval officer is placed, termed the superintendent. The general direction of all the dockyards rests with the Admiralty.

Factories for the repairs of the machinery and boilers of our war ships have been created at all the dockyards except Pembroke. The first con-

struction of the propelling machinery for ships of the royal navy is almost wholly entrusted to private marine engineering establishments. These factories are, of course, of comparatively modern date, but they have already attained large dimen- working the guns, and many other duties. This extensive use of steam power, of course, multiplies the chances of derangement, and it is found desirable to employ from 1,500 to 2,000 men in the factories, to meet the current work on the repairs



PLAN OF PORTSMOUTH DOCKYARD.

sions, and are being considerably extended. Now that war ships are, as has been said, "mere boxes of machinery," it is of the highest importance that the factory departments of the dockyards should be efficient. Steam power is used so freely, in order to reduce manual labour, that it is no uncommon thing to find thirty or forty engines on board a large ship. Besides the main propelling engines, there are engines for pumping water out of the ship, for driving ventilating fans, hoisting the anchors, steering, turning turrets, loading and

of machinery for our war ships. Boiler makers, riveters, fitters, blacksmiths, copper-smiths, pattern makers, founders, and many other trades, are all included in this total. Until very recently, all these workmen were hired, and liable to be discharged when their services were not considered desirable; but it has now become the practice to establish some portion of these men, and to guarantee them a pension, as is customary with the dockyard workmen. A greater hold is thus obtained upon the men than when under

Repairing Basin, Portsmouth Dockyard.

former conditions, and this change in the system promises well.

Although the dockyards provide for the construction, outfit, and repairs of our fleets, they are not manufacturing establishments, except in two or three special cases. Copper sheathing for the bottoms of ships is made at Chatham—this manufacture requiring to be conducted with special care and under watchful supervision. Old iron is also remanufactured at that yard, large accumulations of scraps from all the dockyards being thus dealt with economically. Rope and cordage for the royal navy are made in the roperies at Devonport and Chatham, where machinery of the most improved kind has been erected. But in all these cases there are good reasons for departure from the general rule, that all purchasable articles for war ships shall be procured from private manufacturers, and not made in the dockyards. Anchors, cables, capstans, windlasses, and many other important items in the equipment of ships, are bought from persons not in the service of the State; and the machines, tools, and much of the plant of the yards themselves, are similarly obtained. The Admiralty are also good customers of the timber merchant and iron maker, ship-building operations being carried on upon a large scale in the dockyards. These great national establishments therefore do not compete with private ship yards; nor are they conducted upon commercial principles. The latter fact has sometimes been made a matter of reproach, but there are obvious differences between private and public establishments. Private establishments are carried on for the sake of profit to their proprietors, one of whose chief objects is to minimise "establishment charges," and to keep down expenses on the plant, buildings, and outfit of their yards. The dockyards, on the other hand, are liable to sudden and extensive calls upon their resources; must possess plant and outfit sufficient not merely for ordinary work, but for possible emergencies; have large bodies of men engaged upon the provision and custody of reserves of stores and equipment for the fleet; and in many other respects differ from private yards established simply for the building or repair of vessels not owned by the ship builders. This essential difference is best expressed in the words already used; the royal dockyards are naval arsenals, and important features in the national defence.

The character and scope of the works performed in the dockyards will appear more clearly if, in imagination, we conduct our readers through one of these establishments. Portsmouth yard, which is one of the largest as well as one of the oldest dockyards, will suit our purpose admirably, and our sketch-plan will serve to guide us in the survey. Passing along "The Hard" at Portsea, which Captain Marryat has made famous, the visitor will notice on his left hand large rafts of timber lying aground, or floating in the shallows when the tide is in. These rafts form part of the dockyard stock, and will be brought into use as required. Leaving our names in the visitors' book, kept by the police at the entrance gate, let us advance still in the same direction. On the left of the entrance stands a long range of *mast houses,* where shipwrights are busy making and repairing masts, yards, and spars of all kinds. From the further side of the mast house, a gradual slope leads down to the *mast pond,* where the spars lie almost immersed, in order that they may deteriorate as little as possible before they are brought into use. Opposite the mast house stands the *boat house,* where boats of all kinds are built and repaired, shipwrights being again the artificers employed. A most interesting field of study does the boat house present to the visitor with ample leisure; for boats, as well as ships, include a vast variety of classes and types. Here will be found the tiny "dingey" or "punt," which will hold only a few persons, stowed perhaps inside a huge "launch," which can carry over a hundred people. The life boat, the whale boat, the gig, the cutter, and other kinds of rowing boats, are all represented; while the variety of boats propelled by steam power will startle those not familiar with the changes which have been wrought of late years in this part of the furniture of ships. And strangest of all will appear the "collapsible" boats carried by the troop and store ships, which can be folded up into a very small compass for stowage or transportation, but which, when expanded, can be made capable of carrying troops, horses, and guns.

Passing on, we find on all sides evidence of the fact that this is a great naval arsenal, as well as a ship yard. Long ranges of storehouses, crammed full of all that is required for the equipment of ships, meet the eye. Rigging, sails, anchors, cables, and other articles, are here kept ready for use. One building, approaching a thousand feet in length, can scarcely escape notice: it is the *ropery,* now disused, where formerly the hawsers, cables, and ropes for the port and fleet were manufactured.

Advancing further, the visitor is reminded that such a vast establishment requires a large staff of managers, by passing the offices wherein the admiral-superintendent and the heads of departments are

located. Moreover, he is standing in what was the very heart of the dockyard about thirty years ago, although now it is only one of the outskirts. Before him is the old ship basin, where small ships lie afloat while undergoing the final touches in building or repairs; and within sight there are five or six dry docks, once thought magnificent, but now regarded as of small dimensions. Two hundred years ago, the first dry dock is said to have been built at Portsmouth; now there are no less than sixteen or seventeen docks, the longest exceeding 600 feet in length. The old ship basin covers about $2\frac{1}{2}$ acres; but there are now four other basins, or floating docks, not reckoning a tidal basin, which cover an aggregate area of about 60 acres, the largest of the four having an area exceeding 20 acres.

In his "History of Naval Architecture," Mr. Fincham, who was for many years master shipwright of Portsmouth yard, gives a very interesting account of the earlier operations conducted by General Bentham, at the close of the last century, in extending the dock and basin accommodation. He says:—"General Bentham had to encounter much opposition to the prosecution of his plans of improvement; for the construction of basins, docks, and jetties was the object of strong objections, urged forcibly on the grounds of danger, the impracticability of execution, and the final inutility. Previously to these improvements being introduced, almost all the ships on being fitted out were obliged to have their equipment completed afloat in the harbour, whereas by the use of deep docks, basins, and jetties, ships may have their equipment completed, and can then be taken into the harbour."

The policy thus initiated has been amply justified by experience; and all extensions of the yards, not merely at Portsmouth, but elsewhere, have been accompanied with a large increase of the dock and basin accommodation.

Taking our stand on one of the jetties of the old ship basin, let us look around. The harbour, studded with war ships of all classes, from Nelson's flag ship, the old *Victory*, down to the iron-clad monitor of the present day, is certain to be first noticed. Then the long line of jetties which fringe the harbour and form the outer boundary of the dockyard will receive attention. Alongside may be lying one or two of the magnificent troop ships employed in conveying our soldiers to and from India, *viâ* the Suez Canal. Perhaps one of the graceful paddle steamers belonging to the Royal Yacht Squadron may also be seen, berthed in close proximity to an iron-clad ship, of which the appearance becomes more ungainly by the contrast. The chances are also that our unarmoured war ships will be represented, and the diminutive but important torpedo vessels. Nor should the small craft of the yard be missed—the tugs, the boats, the lighters, and the dredgers, all serving some useful purpose, and all requiring to be maintained in efficient working order. High above the jetties tower the gigantic sheer-legs for lifting masts, or engines, or boilers, into and out of ships; and on every side one meets with machinery or appliances for reducing manual labour and increasing the speed at which work can be performed.

Pursuing a somewhat devious course onwards, crossing caissons or gates at the entrances of docks, and overlooking the workmen busy beneath in the repairs of ships, we shall notice in passing many important adjuncts of the ship-building department of the dockyard. There are the timber sheds, where logs and planks lie stacked; the saw pits, where sawyers are busy cutting timbers to the shapes required; the saw mills, driven by steam power, which do the heavier parts of the work, in which the skill of the handicraftsman is not required. The joiners', painters', and plumbers' shops will also be remarked, and will well repay a visit. The smithery, with its steam hammers and brawny workmen, if not inviting in appearance, is interesting in its processes; so also is the foundry, where the castings in iron or metal which are required for fitting out ships are prepared.

The "building slips" compare very favourably indeed with the corresponding features in private yards, where the object naturally is to reduce the outlay on mere premises to a minimum. A long range of slips at Portsmouth stand side by side, and are all roofed over. The machinery required for iron ship building is placed in the spaces between the slips, and conveniently near the work. The workmen thus sheltered are not interrupted by bad weather, as is often the case in private yards, where the slips are commonly uncovered; and, further, in the case of wood ships this shelter is advantageous to the durability of the vessels.

Great variations occur in the amount of new work which a visitor has the opportunity of observing at Portsmouth or any other yard. He may find most of the slips full, or he may find them all empty. Not so very long ago at Portsmouth the famous iron-clad *Inflexible* might have been seen on the stocks, together with two swift unarmoured cruisers. It is sometimes preferred to build such heavy ships in dry docks; this was done in the case of the *Devastation*, which was built at

Portsmouth. Of late years Portsmouth has not taken so important a share as formerly in building new ships for the navy; Chatham and Pembroke have been more fully employed on that class of work, while Portsmouth, and especially Devonport and Sheerness, have been engaged upon the completion and repairs of vessels. Pembroke is almost exclusively a building yard, and there, or at Chatham, the construction of war ships can be studied even more advantageously than at Portsmouth.

After inspecting the building slips and the machinery, we notice, in the immediate neighbourhood, the engine factory, with magnificent smithery attached, and a shop specially devoted to the preparation of the armour-plating for ships. Mere statements of thicknesses of armour do not appeal to the general reader; but when he sees before him huge masses of iron weighing fifteen or twenty tons, and twelve or fourteen inches thick, he begins to realise some of the difficulties to be faced in iron-clad ship construction. And when he sees these huge plates lifted, bent, drilled, planed, and nicely fitted by suitable machinery, he cannot fail to be impressed with the wonderful power which the use of steam has placed in the hands of the modern mechanic. Nor less is the interest that will be felt in watching the shipwrights fixing and fastening the cuirass on the sides or turrets of the ship, with such skill that, when complete, the surface is almost as smooth and fair as the work of a cabinet maker.

Leaving this department, the visitor comes upon the steam basin, about three times the size of the old basin, which, with the engine factory, was added in 1848, when it became evident that sailing ships must give place to steamers. Here will be seen numerous vessels under repair or being completed, and out of it open some magnificent dry docks. We now stand on the boundary of the older portion of the yard, and are approaching the grand extension, which is scarcely completed even now, although it has been in progress for many years. Convict labour has been employed here, as at Chatham, to a very large extent and with excellent results. The grand scale upon which this extension has been planned will appear from the sketch-plan, and from the statement that whereas the area of the yard was formerly under 120 acres, it will when completed approach 300 acres. The docks and basins already completed and in use form an immense gain to the efficiency of the establishments; when contemplated additions are finished, there will be nothing to compare with it, except Chatham yard, where even more extensive works are in progress.

At length, it may be supposed, we have reached the end of our journey; but there are still other points of interest. To reach these readily, we may avail ourselves of the lines of railway which extend over the yard, and rapidly retrace our way towards the entrance. We shall find that within the circuit of the walls there are enclosed a large number of residences for officers, the admiral-superintendent, the commander-in-chief of the port, and the police who keep watch and ward. There is also a church, a chemical laboratory, a school for apprentices, a mould loft, and drawing offices, and last, but by no means least, the Royal Naval College, wherein officers reside while pursuing special courses of study in gunnery and torpedo warfare. This formidable list of contents is, we fear, incomplete; but enough will have been said to indicate how great is the difference between the naval arsenal and any, even the largest, private establishment connected with ship building and marine engineering.

FOREIGN RIVALRIES.—I.

CONDITIONS OF RIVALRY.

By H. R. Fox Bourne.

THOSE days may come, perhaps, which the Poet Laureate describes in his vision of the future, when

> "—— the war-drum throbb'd no longer, and the battle flags were furl'd
> In the Parliament of man, the Federation of the world;"

but we are yet a long way from them. If, happily, the jealousies of nations and their rulers do not so often show themselves in actual warfare now as in the old times, they exist, nevertheless, and find expression in contests that are none the less keen because they are bloodless. England especially,

which may boast that it has gone far towards abandoning the barbarous device of provoking and settling disputes with other nations by resort to arms, cannot claim to be free from jealousy of neighbouring Powers that are threatening to weaken, if not to destroy, the commercial and industrial supremacy which, during the past few generations, her people have acquired. But, unless patriotism even of the highest sort is an unworthy sentiment, there is nothing ignoble in the alarm with which we must watch the successful rivalry that is being established against us by foreign countries in many of the peaceful arts that were formerly regarded as peculiarly our own. This foreign rivalry, in so far as it indicates the increasing prosperity of the nations that exhibit it, and the growth of happiness among their peoples, is, of course, a clear gain to the world, and a thing to rejoice over, even if it involves some loss of dignity and material advantage to ourselves. To idly denounce it would be as contemptible as it would be useless, and to resort to arbitrary efforts at restraining it would be altogether mischievous. The only wise and patriotic course is carefully to examine its conditions, and the various elements of present and prospective success in it, in order that we may amend our own ways of procedure where they are at fault, and where amendment is possible; and, in those cases in which no adequate improvement is practicable, be at any rate prepared for the inevitable changes that must come about.

Many circumstances have combined to give England an advantage, hitherto, over most, if not all, other nations, in a great variety of industrial pursuits. Whether or not the prime cause was in the bodily and mental temperament of that branch of the Teutonic family which began to take possession of our island a thousand years or more ago, Englishmen have always been conspicuous for their trading enterprise. The guilds that still survive in such bodies as the City companies of London grew out of organisations existing long before the Norman Conquest; and the political privileges acquired by them during the ensuing centuries yielded especially favourable conditions for developing all the crafts and trades that were needed to supply the wants not only of English people, but also of foreigners. "When I consider the true dimensions of our English traffic," wrote Master Lewis Roberts, in his "Merchants' Map of Commerce," published in 1638, "together with the inbred commodities that this island affords to preserve and maintain the same, with the industry of the natives, and ability of our navigators, I justly admire both the height and eminence thereof. The staple commodities of England are cloths, lead, tin, some new late draperies, and other English real and royal [that is, patented] commodities. Shipped hence, in former times, they yielded by their returns from foreign parts all those necessities and wants we desired or stood in need of. But the late great traffic of this island hath been such that it hath not only proved a bountiful mother to the inhabitants, but also a courteous nurse to the adjoining neighbours; for in what matter of traffic they have lost we have been found to have gained, and what they have wanted we have been noted to have supplied them with." The great increase of "the dimensions of English traffic" which thus startled observers two and a half centuries ago had its origin in the skill and energy with which the people not only utilised and multiplied the natural resources of the country, but also brought into it from foreign lands raw materials to be manufactured into serviceable commodities; and the traffic has continued to be mightily developed ever since. Till lately it was almost heresy to doubt that this development would not go on at the same rate for ever. Now, however, we find that, either from accidental or from permanent causes, our commercial progress is, to say the least, by no means so rapid as it used to be, and that in various departments of industrial enterprise foreign rivals are boldly facing us. It is only prudent therefore to inquire how far we are in a position to meet and overcome the dangers that threaten us, even if those dangers do not at present afford ground for very serious alarm. To bring together some facts, and to offer some suggestions pertinent to such an inquiry, is the purpose of the present series of chapters on FOREIGN RIVALRIES IN INDUSTRIAL PRODUCTS.

The most obvious element of success which one country can have in industrial competition with others is the possession of natural advantages for industrial enterprise. In this respect England is fortunate. It lacks many of the materials that are still sources of profit to some other nations, and were in former times of far greater commercial importance than they are now. It has neither gold nor silver mines; it yields no precious stones, or costly spices; and if it now manufactures rich, delicate, and gorgeous fabrics, that vie with the produce of the tropical East, its means of doing so are almost entirely artificial. It was in such commodities as these that the old-world merchants chiefly

dealt, and it was by their help that the first trading nations acquired wealth and industrial importance. Each inhabited district of Europe—every tiny village almost—produced its own simple food, its own rude garments, its own rough tools, without their being looked upon as articles of trade at all. But even in the far-off days when Phœnician traders scoured Persia and India for the only merchandise then held of much account, these traders also made their way to Britain in quest of tin; and as soon as the island became a Roman colony, the new civilisation planted in it found expression in the working up of this and other native metals. Thus a basis was laid for the industrial progress of the English people. The smith, the maker of iron and other tools, was the most important of English craftsmen from the earliest times. "Whence," he is made to ask, in a curious collection of Anglo-Saxon dialogues, "hath the ploughman his ploughshare and goad, save by my art? Whence hath the fisherman his rod, or the shoemaker his awl, or the sempstress her needle, but from me?" Laws were enacted in his favour, and he was encouraged to practise and improve his calling in such ways as not only caused other domestic occupations to be largely practised and steadily improved, to the great advantage of his neighbours, but also led to further benefit from the bartering of his various wares for the more diverse produce of foreign lands. England certainly owes not a little of its greatness to the fact that it is, remembering its area, more richly stored than any other country with the most solid and serviceable of all minerals; and its wonderful industrial development in recent generations is, more than to any other material condition, due to the fact that in convenient proximity to its mines of iron are mines of coal, enabling the iron to be put to uses that would formerly have been regarded as incredible. In the possession of other material resources it is less peculiarly favoured, though its advantages over many neighbouring countries, as regards soil and climate, have also largely contributed to its prosperity. Its indigenous and acquired food resources have only indirectly conduced to the growth of its industries, by giving vigour to those engaged in them. But its forests have yielded, till lately, abundant material for ship building and the like; its flocks of sheep have supplied it with both leather and wool; and by the encouragement of flax cultivation in Ireland, some two centuries ago, facilities were afforded for planting in it another great staple of textile manufacture. The spreading of the English race in distant parts, moreover, and the establishment of English colonies and possessions with conveniences of intercourse between them and the mother country, may almost be said, besides leading to many other industrial results, to have naturalised in England what is now the most important of all textile commodities. Though its special advantages in this respect have now nearly passed away, the addition of cotton manufacture to the manufacture of woollen and linen goods in this country has been in great part due to the favourable opportunities formerly existing for importing the material from America.

The easy possession or acquisition of the actual materials of trade, however, is only one element in industrial success. The articles themselves are of small value unless we have strength and skill to use them. Here, also, England has been notably fortunate. However brought about, the physical —perhaps, too, the mental—characteristics of its people have been, in the main, well adapted to the work devolving upon them. In delicate manipulation, and in artistic refinement, the average Englishman may be surpassed by the average Frenchman, and in other respects the inhabitants of some foreign countries may also be superior to him; but, on the whole, his temperament and capacity, when duly regulated, give him an advantage over all competitors. "Individuals or nations," as Mr. John Stuart Mill remarked, "do not differ so much in the efforts they are able and willing to make under strong immediate incentives, as in their capacity of present exertion for a distant object, and in the thoroughness of their application to work on ordinary occasions. This last quality is the principal industrial excellence of the English people. This efficiency of labour is connected with their whole character—with their defects as much as with their good qualities. The majority of Englishmen have no life but in their work: that alone stands between them and *ennui*. The absence of any taste for amusement or enjoyment of repose is common to all classes. The effect is that, where hard labour is the thing required, there are no better labourers than the English." Other qualities besides muscular strength and endurance, mental energy and perseverance, are needed to make a perfect workman, but these are of most fundamental importance. In spite of all that has been lately said concerning the deterioration of the English labouring classes, they still exhibit them very notably; and there can be no doubt that to their substantial superiority in these respects over the working men of other countries, our industrial prosperity is very largely due.

Hardly less conducive thereto have been the favourable arrangements existing in this country for the employment of capital. Capital, of course, being, in economical phrase, the accumulated stock of the produce of labour in dealing with natural agents, is capital only in so far as it is applied to further production. Happily for England, the same vigour that is shown in the first instance in profitable labour generally continues to be shown in the prudent encouragement of fresh industry by those into whose hands the distribution of capital falls. In England there is no such separation of classes as is indicated by the French division of society into the patriciate and the proletariate. The employers of labour are usually those who, either themselves, or through their predecessors, have acquired wealth by labour; and where the wealth is not immediately employed in direct payment for labour, its ultimate application to that end is, for the most part, hardly less complete. Thus, there is comparatively little waste or destruction of capital, and the stupendous gains of industry during the past few generations have been made eminently serviceable to the further advancement of industry. There is now an increasing and, perhaps, inevitable tendency for surplus English capital to be employed in promoting foreign industry, and thus the interests of England as a rival of other nations may suffer in appearance. Hitherto, however, the gain to England, as a separate nation, has been immense. The abundant wealth of the country, if too much engrossed by a comparatively small number of individuals, has helped to enrich all, by the rapid extension of commerce, and the opening up of new markets and new fields of enterprise.

To the three primary sources of English prosperity which have been noted, others, more or less complex, might be added; but it will suffice to call attention in passing to the beneficial effects upon the industry of the country which have resulted from its political advantages. It is especially to the industrial progress of the English people in past times, leading to the early development of municipal institutions, and the recognition of individual rights, that they owe the overthrow of feudalism among them, long before the victory was gained by any other European nation; and the development of political liberty has inevitably promoted the industrial welfare of the country. Our commercial history shows that much injury has often been done by political interference with the free course of trade. England, however, has suffered less thereby than any of its rivals, and has often profited from the tyranny of which they have been victims. In the stimulus given to English manufactures by the persecution of Protestant workers in the Netherlands and France by Roman Catholic bigots, and their virtual banishment to a less priest-ridden land, we have sufficient evidence of the effect of political meddling with a nation's industries; while the beneficial results of the statesman-like adoption of sound economical principles appear in many recent developments of English material prosperity.

From the foregoing brief review of the main conditions of the industrial progress of England in past times, it will readily be seen what are the principal questions to be answered in considering the present and prospective relations between England and its industrial rivals abroad. Our nation, very fortunately for itself, has had a good start in the race with foreigners. What, we have to inquire, are the chances of its continued pre-eminence, both in manufacturing enterprise as a whole, and in its various special departments?

As regards material resources, what risk is there of its being rivalled or even superseded by the unearthing or cultivation of similar natural wealth in other parts of the world, or by the transference to new fields of labour of the raw produce of which so large a share is still brought into this country, to be manufactured into articles adapted to the growing necessities and the luxurious tastes of all the world? In order to feed our factories, we have encouraged other countries to produce the raw material and send it to be wrought up by us. In many cases they are learning to work it up for themselves, or to send it elsewhere for manipulation. How far are these movements likely to affect our own manufacturing operations?

As regards labour, to what extent are any physical and mental advantages possessed by our working classes likely to be neutralised, either by their own lack of energy, or false views of their dues and their duties, or by the improved education and social advancement of their foreign competitors? Is the system of trades' unions, which has in the main been thus far of great benefit both to their members and to the whole community, in danger now of lowering their capacity for useful work, and of encouraging them to demand such excessive wages as may drive into other countries the occupations on which they depend for their maintenance?

As regards capital, is there any prospect of its being squandered in useless ways by those in whose hands it chiefly rests, or of its being so extensively diverted from domestic channels

as, while enriching other countries, to impoverish England?

As regards legislative and other arrangements, has our wise encouragement of free trade, and our for the most part prudent use of State machinery to foster and develop without harassing or crushing individual enterprise, instructed the people and the rulers of other countries in knowledge that will be injurious to ourselves as a nation? Are the rival schemes of statecraft, in relation to capital, labour, and the materials of trade, which are now being advocated, fitted to aid, or to damage, our industrial progress?

These are some of the questions to which answers will be attempted in our papers on FOREIGN RIVALRIES.

WOOL AND WORSTED.—I.

ALPACA—FIRST PAPER.

HISTORY.

By WILLIAM GIBSON.

ABOUT the year 1833 a well-known wool merchant in Yorkshire endeavoured to find a customer for a consignment of Donskoi. It was a coarse, tangled, greasy sort of wool, which he had imported from South-eastern Russia, and he was prepared to offer it for sale at a very low figure. One after another of the spinners in the district tried the new material, but they all failed to make anything out of it. The following year some of this intractable Russian product got into the hands of a young man who had just started business in a very modest way for himself in a small mill up a back lane in the town of Bradford. Notwithstanding the difficulties attending the operations, he succeeded in spinning and weaving the stubborn Donskoi into a marketable material, and, in consequence, he obtained considerable local renown for his pluck and ability. Somewhere about the year 1836 the same young man, in one of his periodical visits to the wool merchants of Liverpool, happened to go into the warehouse of Messrs. Hegan, Hall, and Co., in that town. There he saw a quantity of long hairy-looking stuff which had lain about for many a year, and which had been hawked in vain through most of the wool markets of the district. Probably this was not the first time he had seen the material, but on this particular day he looked at it with peculiar interest. Remembering, perhaps, what he had been able to do with the Donskoi, the idea struck him that something might be made of this hairy material. The merchant offered to let him have the three hundred and odd bales at his own price, and with a sample under his arm he wended his way back to the inn whence the coach for Bradford started, and in due time reached his dingy little mill in Silsbridge Lane. The young spinner was Titus Salt. The stuff he had brought with him from Liverpool was alpaca. So at last had come together the man and the material that were destined to build up one of the most colossal fortunes ever amassed by a modern "captain of industry." This new wool had travelled all the way from the western coast of South America, and Salt not only worked it up into a novel textile fabric, but he made it into a new material, founded a fresh industry, second in importance only to that of which wool itself is the staple.

Yet alpaca was not absolutely unknown at this time. It was first mentioned in Europe about the early part of the sixteenth century. Pizarro and his famous co-explorers, on their return from their first visit to Peru, brought, among other articles, specimens of alpaca fleeces home with them, together with textures woven from this wool by the natives. Zarate, the historian of the expedition, tells the romantic story of the discovery of the Alpaca sheep. According to him, the conqueror of Peru had been deserted on one occasion by many of his companions, and left on an uninhabited island on the coast of that strange land, with a few faithful friends. Whilst exploring the shores of the mainland in a small boat that was left to them, they came to a pretty bay, with a convenient landing place. Leaping ashore, they were speedily surrounded by natives, who brought them food in the shape of two small animals with long hair, which were killed and eaten. These creatures were some of the native mountain sheep so common in the country, and the only source of wealth to the rude highlanders. From remote antiquity they had been reared and bred for their wool, trained to carry burdens over otherwise inaccessible mountain paths, and were highly prized

because they yielded at once food and clothing for their shepherds and their families. Pizarro, however, and his friends were the first Europeans who had ever seen them.

These South American sheep are classed by Cuvier the naturalist among the *Camelidæ*, or hornless ruminants. Four species of them exist in South America. Two of these—the Guanaco and the Vicuna—are wild, and two—the Llama and Pacos—are domesticated. They were probably named camelettes because in some respects they resemble "the ship of the desert." Like that faithful servant of the Arab, they are burden-bearers, hardy in their nature, and capable of going long distances without drinking water. The best sorts of wool are obtained from the domesticated varieties, but since the growth of the alpaca industry, all four have been shorn of their fleeces, and made the servants of commerce. The wool is either white, black, or grey, and even, sometimes, though very rarely, brown and fawn in colour. It grows from eight to twenty inches long, and is fine in texture, lustrous, transparent, free from crispness, of great strength, and more uniform throughout the fleece than our ordinary wool. Being soft and elastic, and free from spirality or curliness, it spins easily, and yields a true thread which is not liable to *cotting*, or adhering to adjoining threads, and is not injured by being kept for any length of time. The Incas of South America wove this wool pure and simple into beautiful materials, many samples of which have been found, uninjured by the lapse of time, in long-forgotten graves.

LLAMAS.

Early in the present century a flock of thirty-six of these interesting animals was driven by easy stages of two or three leagues a day from their native mountain wilds to Buenos Ayres. There they were shipped for Europe, with a view to their

acclimatisation in the eastern hemisphere. On the voyage, however, most of them died, for only eleven out of the flock arrived in the harbour of Cadiz, in the autumn of 1808. They were sent as a present to Godoy, "the Prince of Peace," as he was called, but almost on the same day as the novel cargo came ashore the great Minister fell into disgrace; and so infuriated were the people at his conduct, that it was with difficulty the strange sheep, which were known to be his, were prevented from being flung into the river. The governor of the city saved them, and gave them to Don Francisco de Theran, a famous amateur naturalist, who had a splendid menagerie at San Lucar, in Andalusia. When the French armies, a year or two afterwards, invaded the province, the soldiers would have destroyed the Peruvian sheep, but Marshal Soult interfered; and Mr. Bury St. Vincent, a naturalist who accompanied the army, had the opportunity of studying their habits. He made drawings of their appearance, which were, however, afterwards lost at the battle of Vittoria; but he had fortunately preserved his notes, and a sample of the wool of each of the four kinds of llama, and it was from a joint report drawn up by him and Don Francisco, which was read before the Academy of Sciences at Paris, that the vigonia and alpaca sheep were crossed, and the heaviest and longest fleeces thus obtained.

In consequence of the prominence thus given to the animal, enterprising breeders were induced to attempt the acclimatisation of the species, and though in the Pyrenees, and even in our own country, the scheme met with partial success, the regular breeding of these sheep has not been generally adopted. Mr. Cross (late of the Surrey Zoological Gardens), Joseph Hegan of Liverpool, the late Earl of Derby, Mr. Stevenson of Oban, and Robert Bell of Listowell, are among those in this country who have crossed the alpaca and our native breeds of sheep with most success. But here the creature seems to miss its clear mountain air, and the herbage of which it is so fond. Except as a zoological curiosity, it cannot be said to exist in Europe.

About the same time as the first flock was shipped from Buenos Ayres, the British troops were attacking that town, and they brought back to England with them a few bales of alpaca wool. This was in the year 1807. Samples of it were shown to the chief wool merchants and spinners in the kingdom, and attempts were made to utilise it, but without any encouraging results. From its introduction to the year 1830 no mention is made of a textile fabric being manufactured from alpaca to any extent. In that year, however, Mr. Benjamin Outram, a scientific manufacturer of Greetland, near Halifax, saw that possibly it might be made profitable, and he had special machinery constructed for spinning and weaving it into cloth. To him belongs the honour of having succeeded in producing the first marketable articles from this material mixed with ordinary English wool. The goods, however, were sold at such high prices, that they were little more than mere mercantile curiosities. Outram wove the alpaca wool into ladies' shawls and cloakings, but the fabrics were destitute of the gloss, fineness, and beauty of later productions, and finding little profit from his venture, his goods, though they were eagerly bought, soon ceased to be offered for sale. Enough had been done, however, to show the possibility of utilising alpaca wool, and other manufacturers took the matter up. Among others, Messrs. Wood and Walker spun it to some considerable extent for the camlet trade of Norwich; and about the same time it was occasionally used in place of what is known as "hog" wool, and spun to the fineness of thread number 48.

Its first introduction to Bradford—the place destined to be the future centre of its manufacture—came about in rather a curious way. In 1832 some gentlemen connected with the trade to the west coast of South America were paying a visit at the house of Mr. James Garnett, of Clithero, who did a large business with that part of the world. Mr. Garnett suggested that trade might be indefinitely increased between England and Peru, if the merchants in this country had some articles which might be interchanged for the raw products of that rich belt which borders on the Pacific. Mr. Garnett had heard of the alpaca wool and the cloth that had been made from it. He proposed that a few pounds should be sent to him in order that he might ascertain from his friends in the wool trade whether it had any commercial value. In a few months he received a small quantity, which he forwarded to Messrs. Horsfall, of Bradford, on the 2nd of October, 1832, with a request that they would test its manufacturing value. Having the experience of Mr. Outram and others to guide them, the Messrs. Horsfall set to work, and out of the alpaca made a piece of cloth resembling heavy camlet. This piece was shown to Leeds, Bradford, and Manchester merchants, but the price they were obliged to ask for it, and the unpromising appearance of the cloth itself, caused them to decline to have anything to do with it.

These various experiments, however, had one gratifying and useful result. They called the attention of importers of wool to new and strange materials, some of which might be found to succeed as products of manufacture. Amongst the earliest to discover the possibilities that lay in alpaca, were the Messrs. Hegan, Hall, & Co., of Liverpool, who, in order to meet the demands of such pioneers in the new trade as were experimenting with the material, directed their correspondents in Peru to ship over parcels as ordered. About the same time as the Messrs. Horsfall were opening the private parcel forwarded to them by Mr. Garnett, other spinners were trying what could be done with mixtures of worsted and alpaca. Hitherto all the attempts had failed because wool was used for warp, and it was thought alpaca might yield better results with worsted. The kind of goods now made were figured as in union damasks and kindred materials, the flowers being raised in alpaca on the worsted ground. These fabrics, however, were in vogue only a short time, and as they did not suit the public taste, their manufacture was soon abandoned.

Such, then, is the history of the alpaca manufacture in this country up to the year 1836, when young Titus Salt made his memorable journey to Liverpool. Having brought home his not very promising sample of alpaca, he at once applied all his energies and knowledge to solve the problem of working it into a saleable cloth. Nor was the task an easy one. The length of the wool presented the initial difficulty, for it rendered the ordinary combing apparatus practically useless. Special machinery had, therefore, to be made, with teeth very much longer than the old hand combs, which up till that time had almost exclusively been used in the Bradford district. Titus Salt was not a man to be easily thwarted in any enterprise, and the more he experimented the more he perceived the value of the material with which he was dealing. Old Bradfordians know the stuff of which the great manufacturer was made, and some still alive are able to remember how the dingy little office of the small mill in Silsbridge Lane was to be seen at nights lighted up hours after the other portions of the building were shrouded in darkness. The reader can fancy that the young inventor was then busy with his newly-found alpaca, and that, baffled and defeated, he still clung hopefully to his purpose. Doubtless, too, in the course of his weary vigils, descriptions of those beautiful fabrics that had been woven ages ago by the ancient Incas haunted his fancy. Compared with the products of the Peruvian makers, English efforts so far bore the same relation in regard to fineness of workmanship that coarse sacking does to the most delicate French cambric; and he knew that unless he could far outstrip the rude results of the Outrams, the Horsfalls, and others who had been first to engage in the new trade, he was doomed to the same disappointment that had overtaken them. But defeat was a word unknown to young Salt, and he held bravely on.

Three things had been apparent to him from the outset as necessary to bring the new material within the means of the ordinary consumer. These were—first, the preservation of the natural gloss and beautiful colours of the wool as it grew on the back of the sheep; secondly, its successful admixture with some easily obtainable and cheap thread; and, thirdly, the construction of such machinery as would lower the cost of production by rapidity of manufacture. Hitherto Bradford had been satisfied with old-fashioned implements. Combing, spinning, and weaving by hand were still common, and there was a natural prejudice against the introduction of machinery to mills and factories. A struggling manufacturer himself, the outlay of a few pounds was a serious thing to Salt, and should he fail it might prove still more disastrous. However, machinery of some sort he was forced to have, and that by which he ultimately succeeded in making alpaca had, in the first instance, to be designed, if not made, by his own hands. It was out of the question to contemplate manufacturing alpaca pure and simple, and at first he experimented, as his predecessors had done, with an admixture of woollen and worsted warps, as those best known, and most accessible to him. He soon saw, however, that neither of these was fitted to mix with the delicate fineness of the alpaca, and for a time his venture was at a standstill. At last the idea struck him that cotton might answer his purpose, and tremblingly he tried it. Already he had spun his sample into beautiful threads, which looked glaringly out of place with unequal wool, or the more jagged worsted. When tried with cotton-warp of a corresponding fineness, the alpaca weft made a beautiful cloth, and the problem was so far solved as to warrant his taking a decided step. Though he had discovered how to utilise the raw material, he was yet without the means of taking full advantage of the knowledge, and he was so far only on the threshold of success. However, the first thing to be done was to buy the wool that lay stored in the warehouse of Messrs.

Hegan, Hall, and Co., at Liverpool. For that purpose he scraped together every penny he could spare from his already rapidly-growing business, borrowed the rest from his friends, and wrote to the Liverpool merchants that he was willing to take all the alpaca they had in stock at 8d. per lb. Messrs. Hegan and Co. were only too glad to get rid of their cumbrous consignment at any price. The whole three hundred and odd bales were soon spun and woven, and alpaca of a saleable sort was for the first time ready for the English market.

perfection in the earlier that there is in the later products of his looms. But even such material as he was then able to offer to the public caused considerable stir in the markets and shops of Leeds, Manchester, and London, and speedily the demand for it grew apace. It was the very thing the ladies had been looking for—a fabric cheaper than silk, yet resembling it in glossiness, showy and elegant in appearance when made up into dresses, and though perfectly fit for summer wear, yet more durable than anything they had hitherto seen.

Alpaca Sheep.

Here, however, a fresh difficulty started up. It was not everything to make goods, as Titus Salt found. Dealers had been bitten before with fabrics from the same sort of wool, and they were shy of buying. The merchants of those days had to deal with a public less eager to leap at novelties than that of our own time, and the consequence was that the new goods hung on their hands longer than they liked. Salt, however, had faith in his alpaca, and foresaw that it would become a favourite with the ladies. Traders might shake their heads, and the public shrug its shoulders, but he saw farther than they did, and he at once set about perfecting his machinery and providing for a regular supply of the raw material at as cheap a rate as possible.

There was, of course, nothing like the beauty and

Very soon Mr. Salt was obliged to remove from the small mill in Silsbridge Lane into larger works, and the ball of fortune, once set rolling at his feet, daily gained in momentum. The young manufacturer, at the end of 1840, was already on the high road to success. Competitors sprang up on all sides, but those goods with the brand "T. S." were always the best, and the original manufacture holds a proud pre-eminence in the trade up to the present hour. Indeed, the brand "T. S." had then, and retains still, a monopoly in certain sorts of alpaca goods.

With the development of the industry, the number of manufacturers has multiplied, and as the supply of the article has increased, the demand for it has proportionately augmented. But for all practical purposes it may be said that the history of the alpaca

trade centres in the firm which first made it popular, and that a description of the works at Saltaire will be an exposition of the best and most successful processes of its manufacture. We shall, therefore, chiefly confine ourselves to that remarkable alpaca town which has sprung up within a few miles of Bradford, the works of its creator, and the processes by which the raw material is converted into the marketable fabric. The growth of the trade will, however, be most easily set forth by a plain unvarnished statement of the quantities of alpaca imported into this country during various years since Messrs. Hegan, Hall, and Co. first disposed of their stock to young Titus Salt. The total quantity of the wool imported into England in 1837 was, in round numbers, 570,000lb. After a lapse of ten years, the quantity had increased to 1,500,000lb., and in 1854 it had risen to no less than 2,300,000lb. Coming down to the year 1864, nearly 2,800,000lb. were brought into this country; but this comparatively slight advance may be accounted for by the general depression of trade caused by the war in America. In 1872, however, the importation had leaped to 3,878,739lb., in 1874 to 4,186,381lb., and in 1875 to 4,600,000lb. In 1876, just forty years from alpaca coming into general use, as much as 5,000,000lb. must have reached our shores from South America, Northern Hindostan, and the other sources of supply in different parts of the globe. So that to-day, for every 5lb. of alpaca formerly used by our English mauufacturers 1,000lb. are now worked into various textile fabrics. The price per lb. in 1836 was, as we know, 8d., but in a year or two it advanced to 1s. per lb.; in 1856 it was worth about 2s. 6d.; and at present prices range from 2s. 10d. to 3s. per lb. Notwithstanding this increase of price, however, alpaca stuffs are cheaper in 1876 than they were in 1856, and, of course, offered for infinitely less than the price per yard which was obtainable for them twenty years previously.

IRON AND STEEL.—II.

THE BLAST FURNACE, AND WHAT FEEDS IT.

By William Dundas Scott-Moncrieff, C.E.

SINCE the introduction of the hot blast, the preliminary process of calcination of the ores has been greatly abandoned, and is only carried on when they contain an excessive amount of carbonic acid, water, or volatile matter which may need to be driven off by "roasting." Ovens built for the purpose are the best means for doing this; but practically the roasting is generally performed by mixing large heaps of coal and iron ore in the open air, and allowing them to burn themselves out. In Scotland, the black-band and clay-band ironstone ores are so full of coaly matter that the roasting is carried on with little or no additional fuel. If we now take the materials already referred to in connection with the hot-blast furnace at the Coltness Ironworks, viz., coal, calcined ironstone, and broken limestone, we shall see what goes on in the furnace.

A great many elaborate experiments have been made by distinguished chemists to discover the exact nature of the changes which go on in the process of smelting. So long ago as 1845, Messrs. Bunsen and Playfair reported the result of their investigations on this subject to the British Association. In order to determine these, the furnace was divided into zones, from which the gases were extracted by means of pipes made of malleable iron, which were allowed to descend into the furnace along with the gradually descending materials of the "charge." In these experiments the gases could not be collected at a depth lower than the top of the boshes, but Mr. Ebelman, by boring through the masonry only three feet and a half above the nozzles or "tuyères," obtained gases which were conveyed and collected partly through porcelain tubes and partly through gun barrels lined with porcelain. As these experiments deal with the furnace during different periods from the time of charging, and with different kinds of fuel, they are somewhat beyond the scope of the present paper; but we may give Mr. Ebelman's conclusions drawn from his investigations upon a furnace which was fifty feet in height. The air thrown in, according to his observations, produces successively carbonic acid and carbonic oxide at a small distance from the nozzles; the former attended by a disengagement of heat, the latter by a re-absorption of the principal part previously disengaged. The ascending current of carbonic oxide and atmospheric nitrogen produces these effects: it heats the descending column of minerals, it becomes charged

with volatile products disengaged from the fuel, the limestone, &c., and it reduces the oxide of iron to the metallic state. Looking more to the solid materials, and less to the gases, it may be said that the upper contents of the furnace, as they approach the intense heat produced by the combustion of the fuel in contact with the blast, become gradually softened. In this state the limestone parts with its carbonic acid and attaches itself to the earthy impurities of the ironstone, which are thus amalgamated into a slag. The metallic iron is left to descend slowly till it accumulates on the hearth, where it is deoxidised and thoroughly melted. In its passage through the furnace the iron becomes carbonised, and in this condition, before the blast has had time to burn away the carbon that has got into it, it is run off into a channel which is called the "sow," from which it fills the moulds that are known as "pigs." The slag, which is continually forming during the smelting process, floats upon the surface of the melted iron, and is allowed to flow away continuously from the top of the "dam-stone." At the end of every twelve hours—more or less, according to the condition of the furnace—a plug made of sand, clay, and powdered coal is removed from the dam-stone, and the operation of tapping the melted iron is repeated. Of the more recent improvements in the blast furnace, more especially those which refer to the utilisation of the waste gases, we shall again have occasion to speak.

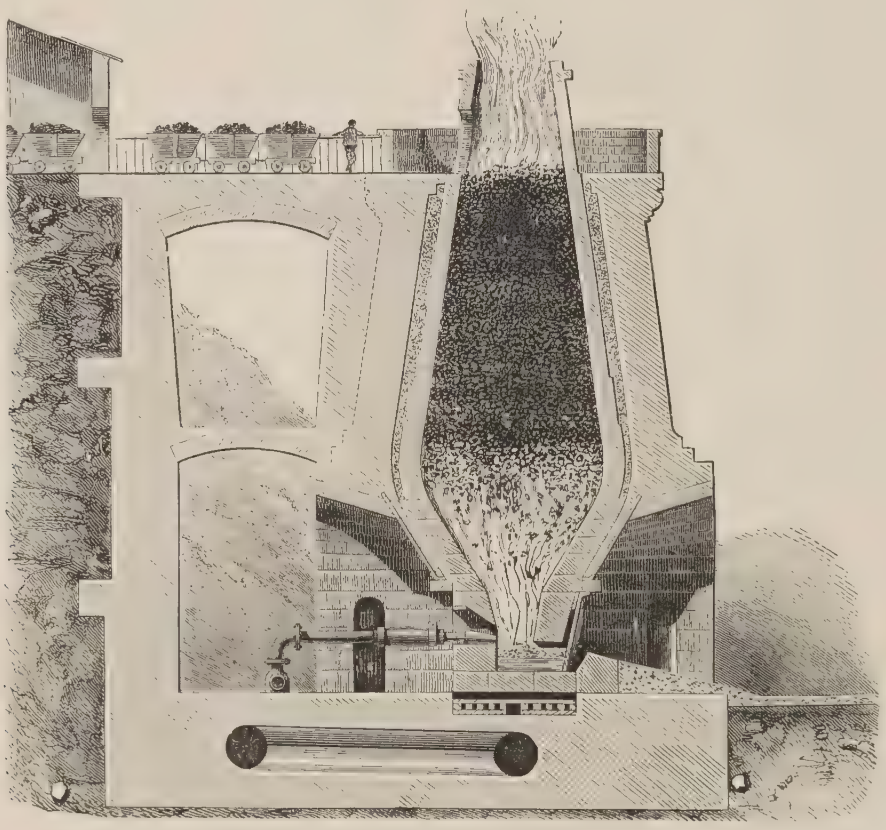
Let us now say something about the ores that feed the blast furnace—the crude minerals from which iron is obtained. They are diffused so widely over every part of our globe, that it would be beyond the limits of the largest treatise to speak of every known kind and district in detail. The supply seems to be sufficient not only for the requirements of our own time, but for those of innumerable ages to come. There was no more interesting feature of our Great International Exhibitions than the display of mineral wealth which was brought together, to the astonishment of mineralogists, who were ignorant until then of how rich the world was in iron. Specimens of ore, as fine as any that ever filled the pockets of a British ironmaster, were sent from the distant wilds of Canada, and the story of the mines from which they came, telling of beds of ore hundreds of feet in thickness, seemed at the time to be almost beyond belief. Yet these vast stores, after having tempted a few adventurers to erect furnaces in their neighbourhood, have been almost entirely abandoned. They must wait till future waves of emigration render the working of them profitable. In some cases the ores were so rich in the finest descriptions of iron, that they were conveyed in the crude state as back freight in vessels that had taken cargoes to Kingston, on Lake Ontario, and found their way to the blast furnaces at Pittsburgh, in Pennsylvania. Unfortunately the discovery of mines more conveniently situated soon put an end to this traffic. As has already been said, iron is seldom found in its pure or "native" state. In the rare cases in which it is so seen there are a few in which the metal has reached our planet in the form of meteoric masses that have, as it were, "dropped from the clouds." At Yale College, in America, there is preserved an aërolite or meteoric stone, containing about 90 per cent. of pure iron and 10 per cent. of nickel. It weighs 1,635 lb., or nearly 15 cwt., and measures 3 ft. 4 in. in length, 2 ft. 4 in. in breadth, and 1 ft. 4 in. in height. A meteorolite of about the same weight was discovered in Siberia, and others even larger have been found in South America. These, however, from their rarity, are of no commercial importance. The different combinations which iron assumes, both in its crude and manufactured state, with oxygen and carbon, are so distinct in their character that for all practical purposes they may be looked upon almost as if they were different metals; and it is of these combinations, mingled with various impurities, that what may be called "the iron ores of commerce" consist. The different combinations of the same iron—it may be, for instance, of pieces of a homogeneous bar with carbon alone—bring about such radical changes in the properties of the resultant products, that these are more distinct in many respects than some metals that have positively no chemical similarity or relationship whatever. Deprived not only of carbon, but also of all possible impurities, iron becomes useless except for medicinal purposes. Strangely enough, it is the only metal that is necessary, as a constituent element, to the sound structure of the human frame. Iron is so soft that it can be scratched with the finger-nail, and is readily worn away by friction. And yet, when combined with carbon in different ways, it becomes so altered in the qualities of hardness and tenacity, that it is capable of cutting in the form of steel what in an earlier stage of its carburisation was malleable iron. In other words, if we take a bar of wrought iron, and, dividing it into two pieces, treat one half with carbon, and form it into a suitable tool, we shall then be able to shear the other half into shreds,

It so happens that the process of smelting iron with charcoal, coke, or coal, in a blast furnace almost always supplies it with an excess of carbon. The result is that the metal obtained in this way, technically known as "pig iron," is the most highly carburised of all the forms of commercial iron. Even the degrees of carburisation that take place in the same furnace, during different intervals of the operation of smelting, are sufficient to stamp their characteristics on the metal, and give rise to the terms, No. 1, 2, or 3 "pig," No. 1 being the most highly carburised, No. 2 less so, and so on, in some cases down to No. 4. The terms grey, mottled, and white "pigs," arise from the same conditions, and represent the combinations of what scientific men call "combined carbon," and "graphitic carbon," with iron—combinations which to this day are scarcely understood by the chemist and metallurgist. The highly carburised condition of the iron in a blast furnace, besides being the natural result of the process, may be looked upon as necessary, because a large amount of carbon is necessary to produce fusibility and fluidity in the ores; and without this being effected, of course the process of smelting could not be carried on. It is this condition that creates the difference between the melting-point of cast iron and malleable iron, and it is familiar in practice to every village blacksmith. If he subjected cast iron to the full heat of his forge, it would pour out of the hearth. If, on the other hand, the metal in a blast furnace were allowed to be so much deprived of carbon as to get into the state of malleable iron, it would solidify, and, by ceasing to flow, choke up every opening provided for its removal.

It will now be readily seen that, as the combination with everything except carbon and oxygen is injurious to iron, speaking generally, it is only those ores which consist of a large percentage of iron and carbon, or oxygen, that are of any commercial value. There are some substances, such as silica, that are almost invariably present in every variety of manufactured iron, and which do not seem to spoil its usefulness. But most other admixtures, especially sulphur, are injurious, and when they occur in large quantities, render the iron entirely unfitted for any practical purpose. Among the few foreign substances that improve iron is phosphorus, which is supposed to render it more easy of melting. Hence it is often present in the metal used for fine ornamental castings, because when tainted with phosphorus the molten iron runs more freely into the delicate intricacies of a decorative mould. It will also be seen from these explanations that where the impurities of iron ores consist of carbonaceous matters adhering or mingling with the ore, as in the famous "black-band ironstone" of Scotland, they are not injurious, because they perform much the same part in the smelting process as the fuel itself. It is very necessary now that the reader should understand that when iron is in a molten state it is eager to combine with any impurities that may come in contact with it. Therefore the ironmaster must not only have the purest possible ore, but the finest possible fuel to smelt it with.

Reverting to a consideration of the ores themselves, the first great class that generally stands at the head of the list are called "the magnetic oxides." They are the purest ores which exist, and it is from them that we obtain the finest Swedish iron—the metal that is converted in this country into the thousand and one articles that are known as cutlery. Supposing it be pure, a bit of magnetic oxide will consist of 72·4 per cent. of iron and 27·6 of oxygen. In Sweden it is often found in a massive state, and occurs in veins among various crystalline rocks, such as granite, quartz, hornblende, marble, &c. In some cases, no flux such as is almost invariably required, in the form of lime, is necessary to smelt magnetic oxides, as they supply, sometimes, a fusible slag of themselves, when properly mixed together before being put into the furnaces. When such fine ore as this is smelted with charcoal, which contains none of the impurities of coal, with which iron is generally smelted in other countries, it may well be supposed that the quality of the iron produced is the very best that is known to commerce. Besides these rich and pure ores which are found in Sweden in veins and masses, there are others which are found in the lakes and bogs, and which on this account are called bog ores and lake ores. In the Swedish department of the International Exhibition of 1862, there was a large assortment of these ores, which are sub-divided and designated, according to their appearance, there, as *pearl ore*, *bur ore* (Borr-malm), called after the head of the burdock, *gunpowder ore*, *cake ore*, and *money ore*. The way in which these lake ores are collected is very curious. When the lakes are ice-bound, the miners, or rather gatherers, go out "prospecting," somewhat in the fashion of gold-diggers. They first of all make small holes in the ice, through which they pass a pole long enough to reach the bottom—which is generally at no great depth, as the ores are collected among the shallows and reed-

beds. By long practice the collector knows by the sound of the pole as it strikes ground whether or not there is ore on the bottom; and when he discovers it, he stakes off his "claim" with pegs driven into the ice; and to this he has a legal right. When he has fixed upon the scene of his future operations, he makes a hole, about three feet in diameter, on the boundary of his "claim," and through this he passes a sort of sieve fixed to the end of a pole, which rests on the ground. By means of a rake about two feet broad, secured to a long handle, he collects the ore into a heap, and then with a smaller rake he fills the riddle which is then pulled up, and has its contents emptied upon the ice. The ore has afterwards to be washed and freed as much as possible from the mud and other impurities which adhere to it. In the province of Sveäland this industry gives employment to a great many people during winter, and a skilful man can collect from half a ton to a ton of ore in a day. The thickness of these beds of ore varies from eight to thirty inches, and after being exhausted they are said to be renewed in about twenty-five years. There is some difference of opinion as to the origin of these beds of lake ore. The most plausible theory to account for them would, of course, be that which attributed them to the sedimentary deposits washed down into the lakes by rivers from the surrounding country. But Mr. Sjögreen, who wrote an account of these curious ores for the Exhibition of 1862, believes that they are of infusorial origin. If this be the case, iron beds might be planted in other lakes than those of Sweden, in conditions favourable to the growth of the *animalculæ* that build them up. In 1860, according to the Swedish Board of Trade Report, published in 1861, there were 22,000 tons collected from the lake beds in the strange and laborious fashion just described. Owing to the inaccessibility of the country, the iron industries of Sweden are carried on under great difficulties, and in many districts it is necessary to wait till the frost has provided the means of sledging in order to convey the fuel to the furnaces. It is not only in the purity of the ore and the fuel that the Swedish ironmaster keeps the lead in the quality of the iron he produces; in every point of the manufacture he is most careful and conscientious. If any injurious substances are combined with the ores, they are thoroughly got rid of by roasting them before they are put into the furnace. The smelting in some districts being conducted on a large scale, the capital of any one proprietor of minerals or forests is often



SECTION OF BLAST FURNACE, SHOWING ITS FOOD.

Swedish Peasants "Prospecting" for Lake Ore.

insufficient to carry on the business, and so mine owners combine to share the expense of constructing smelting works. In this way it often happens that a blast furnace is very much in the position of a rural mill, to which people send their corn to be ground, and ores and fuel which are the property of several persons are often melted in the same furnace at the same time, the products being shared in the proportions in which the raw materials were supplied. The importance of the ores of magnetic oxide of iron depends not so much on the large quantities which exist as the valuable nature of the manufactured iron which is obtained from them. Here we may remark that it is in this class of ore that the mineral wealth of Canada, already referred to, consists; and as immense fields are found in the United States, the Transatlantic supply may be said to be almost inexhaustible. In England this kind of ore only occurs very rarely, though it has been found at Dartmoor, in Devonshire, containing 57 per cent. of iron.

There is no scientific classification of iron ores based upon any principle of chemical analogy, but those of the next importance to the magnetic oxides are the hæmatites, which largely abound in Great Britain, and have within recent years been greatly increased in value by the introduction of the Bessemer process of manufacturing steel, for which they are particularly adapted. They are further divided into the two classes of red and brown hæmatite. The red kind usually occurs in the strata of rocks known as the carboniferous limestone, and varies in appearance, being sometimes hard and compact, with cavities lined with crystals of quartz, as at Cleaton Moor, in Cumberland; but generally soft and unctuous, like the *débris* of bricks that had first been softened in some way and then beaten down till the largest lumps were about the size of a strong man's fist. It is principally found in Cumberland, but it also exists in Lancashire and Glamorganshire. It is most frequently met with under ground, but sometimes it lies on the surface. In Cumberland, the very finest description of this valuable ore is found in beds 15, 30, and even 60 feet in thickness, and within a few years has raised that county to the position of one of the wealthiest in the kingdom. The brown hæmatites are generally of an earthy appearance, and of an ochre-brown colour. They exist in great quantities in the Forest of Dean, and also in Northamptonshire and Staffordshire. A bed has also been discovered in Ireland, in the neighbourhood of Belfast. They do not contain nearly so much iron as the red hæmatite, the average samples showing about 40 per cent. In some parts of Devonshire the ore is ground down in mills constructed for the purpose, and being mixed with linseed oil, makes a capital pigment, which is especially useful for painting ironwork. Both brown and red hæmatite ores are at present being imported to a large extent into this country from Spain.

Within a comparatively recent period a very interesting species of ore has been worked in England, called spathic, or sparry carbonate. It is an oxide of iron, like all the others, but contains a large percentage of carbonic acid, along with a sufficient quantity of manganese, to give very peculiar properties when smelted at low temperatures. It produces the same sort of iron as that which is known in Germany as *spiegeleisen*, and represents one of those puzzling combinations of iron with carbon, about which the chemists seem quite unable to agree; it has a beautiful white mirror-like fracture, and though apt to burn away very rapidly in the process of "puddling," when being converted into malleable iron, the quality of the metal obtained is very fine. *Spiegeleisen*, as applied to the manufacture of iron and steel, has been the subject of numberless patents, one of which was taken out by Mr. Robert Mushet, in 1856. This patent afterwards appeared to be of immense pecuniary value, but was abandoned in the third year, so that the discoverer of the process reaped no advantage; although afterwards greatly employed in the Bessemer process, being mixed in a molten state with the "charge" to produce a definite amount of carburisation after the whole carbon has been removed. Space does not permit of our giving any elaborate account at present of the distribution of these ores over the continent of Europe, where they occur in great quantities, more especially in Westphalia and Styria, where the *spiegeleisen* is principally made, so we will conclude with a short description of by far the largest iron deposit of Great Britain. This is the argillaceous, or clay and black-band ironstone of the coal-measures, and the geological formation known as the Oölite and Lias. It occurs in such quantities, and in such close proximity to the fuel necessary for smelting it, that it has altogether altered—we might almost say, begrimed—the face of the country in the neighbourhood of its manufacture. As most folks know, it has given to a great part of Staffordshire the name of the Black Country. Mr. Jukes, in speaking of the iron ores of South Staffordshire, says, "In no other coalfield of the United Kingdom is a thickness of

30 ft. of coal to be found together; while in South Staffordshire twelve or thirteen beds of coal rest one upon another, with but very light partings of shale between them; and I believe the quantity of ironstone to be found in this district within a vertical space of 100 or 150 yards is greater than is known anywhere else." In the Derbyshire coal-field, these valuable deposits occur in great abundance, and besides forming the great mineral wealth of Scotland, from which the princely fortunes of the Bairds and others have been accumulated, they are worked to a great extent also in Yorkshire, Warwickshire, Worcestershire, and North and South Wales. At one time they were melted in Sussex, and beds of them may be seen in the cliffs near Hastings. Dr. Price states that he has seen truckfuls of this ore at the Ebbw Vale works, which had been dredged up from the sea, off the coast of the Isle of Wight, and sold at Cardiff at 10s. per ton.

The fuel necessary for smelting the other ores of this country has to be carried to the ores, or the ores to the fuel. But in the case of these argillaceous ores, there is not only an ample supply of fuel, and generally of limestone flux, for the purposes of smelting and manufacturing them, but, as if Nature could not be sufficiently bountiful, she has mixed up with the ore itself a sufficient amount of carbonaceous matter to admit of its being roasted and freed from many of its impurities with the aid of little or no additional fuel beyond what is attached to it as it comes from the mine.

MODEL ESTABLISHMENTS.—I.

MESSRS. JOHN PENN AND SONS, MARINE ENGINEERS, GREENWICH.

By Robert Smiles.

A NUMBER of important conditions should be complied with to entitle a large industrial concern to be designated a model establishment. Among others, a compact site should be chosen for the works, rectangular by preference; convenient arrangements for consecutive processes; machine and hand tools and appliances the best of their kind for the operations undertaken; abundant light and ventilation. Among other than physical conditions, the relations between employers and employed should be marked by reciprocal goodwill and thorough cordiality. Another requisite, supplementary rather than essential, should perhaps be, that the establishment is the foremost of its kind, or *sui generis.* Messrs. John Penn and Son's works conform to all of these conditions excepting the first, of which more anon. In those works are made most of the largest and best marine engines anywhere produced, and throughout the world the name of John Penn is more than favourably known among engineers and navigators.

The works consist of two large establishments: one in which the engines are designed, the separate parts produced, and the whole constructed, or "fitted"; the other, or "lower shop," in which the boilers are put together. This paper relates to the engine works, of which we give a free sketch-plan, from which it will be seen at a glance that the works do *not* comply with our first condition, as to compactness or rectangular form. The irregularities of form and arrangement are attributable to the simple fact that the extensive works, which now occupy about seven acres, are accretions upon a small germ; plot having been added to plot, as they could be acquired, to meet the growing exigencies of the business.

It may be well to refer briefly to the growth of the world-wide reputation of the firm. It was founded about the beginning of the century, by Mr. John Penn, grandfather of the present worthy bearer of that name. He was a man of remarkable natural and acquired ability, and, *inter alia*, a keen politician, and friend of William Cobbett; indeed he was a candidate for the representation of Greenwich at the parliamentary election that followed the passing of the Reform Bill in 1832. From his savings as a workman he purchased a property in Greenwich, built a smith's shop, and commenced business in a small way. His first important work was the execution of a large contract with Government for machinery and apparatus for a bakery at the Deptford victualling yard, which he completed to the entire satisfaction of the authorities.

Mr. John Penn, his son, who in 1874 retired from the firm, had a strong natural bent for mechanical pursuits. He willingly accepted his father's tutelage and training, and when still a comparatively young man became, so to speak, his father's right hand. It was during the reign of John Penn

secundus, and very much owing to his inventive skill and constructive ability, that many marvellous improvements were effected in the machinery of marine propulsion. In his time, and in the works of the firm, engines of all grades and powers were designed and erected. A list of the vessels fitted with engines by Messrs. John Penn and Son would occupy more space than can be spared, and would be only dry reading; but the starting-point in their career as renowned engine builders demands a word of reference. In 1836, a number of boats, built on very fine lines by Mr. Ditchburn, were put upon the Thames to ply between London, Greenwich, and Woolwich. These were fitted by Messrs. Penn with oscillating engines, that proved themselves in all respects greatly superior to those on the side-lever principle. The royal yacht-tender *Fairy* was built on the same pattern; her engines, of the same type, were fitted by Messrs. Penn, who also applied the screw propeller to the *Fairy*, which was one of the first vessels in Her Majesty's navy fitted with this kind of machinery. Among the first of the ships of the navy fitted with their improved oscillating engines, by Messrs. Penn, were—the *Black Eagle*, the *Sphynx*, the *Banshee*, and the royal yacht *Victoria and Albert;* also the renowned Australian liner *Great Britain*, and many other ships for the navies and mercantile marine of various countries. These engines proved equal in power, although of only about half the weight of those constructed upon the side-lever principle, and some of the ships attained unusually high speeds.

The engine works show, externally, large surfaces of roofing, and long ranges of wall, but they have no decorative elevation, certainly no grand façade. The entrance used by the heads of the firm, managers, clerks, draughtsmen, foremen, &c., is at the junction of John Penn Street with Lewisham Road. This entrance is only a few yards wide; from it the natural contour of the ground dips by a rather steep incline. Passing through the outer door and down a few steps, a hall is reached, with on each side ranges of well-lit offices, and counting, model, waiting, and other rooms. Over all these, on a first floor, is a large drawing office, admirably lit, partly from the roof. In this part of the premises, marked o o o o o in our sketch, the initiatory steps are taken in connection with every engine or boiler produced by the firm. On the ground floor, the "interviewing" and the correspondence, of a polyglot character, that precede orders or contracts, are conducted. Preliminaries settled, the work is passed upstairs, where complete drawings and specifications are prepared by chiefs of departments, in concert with the heads of the firm. From the finished designs working drawings are made, showing in exact proportions the minutest details, down to rivet and bolt holes. These drawings are passed to the head foremen in the different shops, who are responsible for the production of the numerous and varied parts that are to be brought into harmonious combination in a vast and complex machine. With the distribution of the working drawings among the foremen, the actual manufacture of the engine may be said to begin, and will give full scope to watchful oversight and skilled work. On the inner edge of the office hall other doors and a flight of steps give access to the erecting shop and heavy turnery, and from it to all other parts of the works.

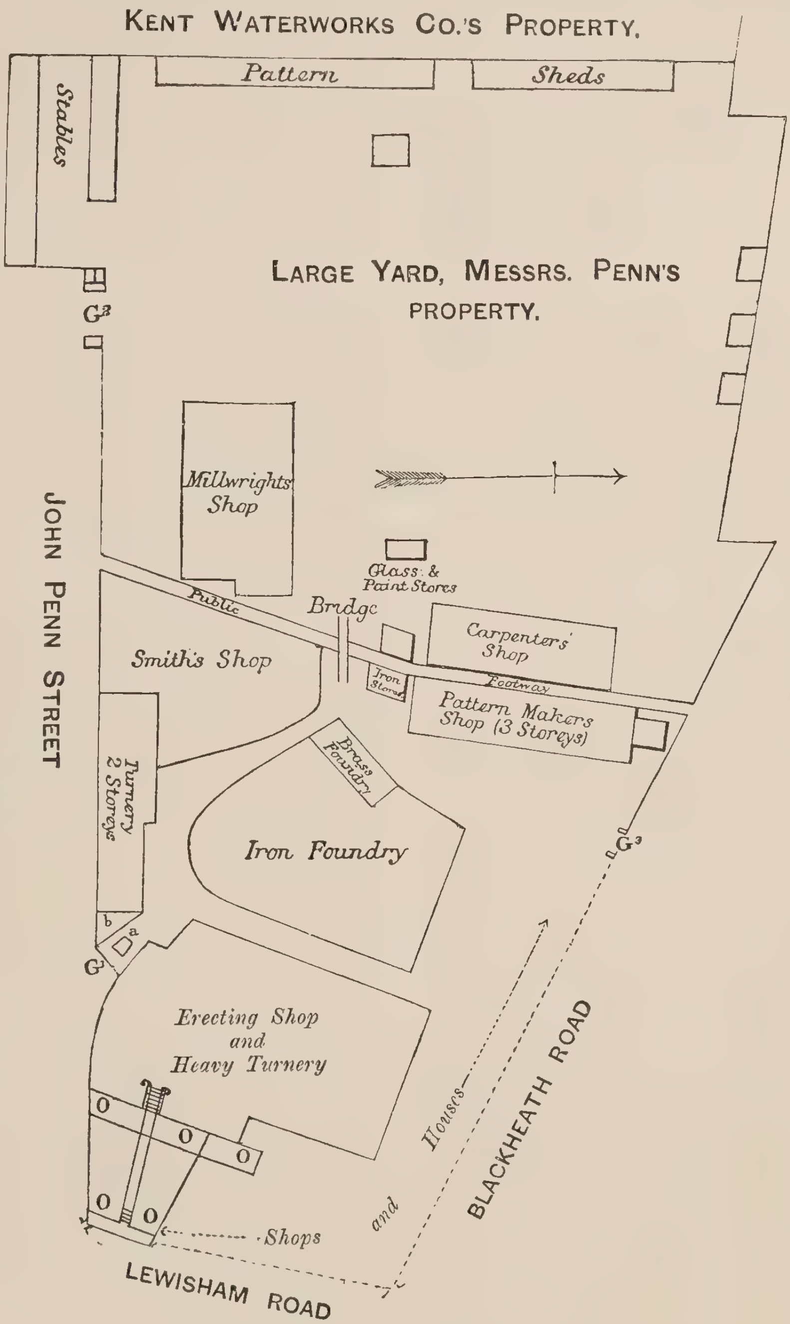
Reverting to our sketch, it should be mentioned that the entrance for the workmen is by a wide gateway (G^1) in John Penn Street, where the timekeeper has a lodge (*b*). This is also the principal entrance and exit for raw materials, and for finished work. A powerful weighing machine (*a*) is placed within the gate, upon which the loads are weighed when necessary. The gateway referred to, it will be seen, affords ready access for pig iron to the foundry, malleable iron to the smiths' shop, timber to the carpenters', and materials for the different departments. For the convenient transport of raw material and of work *in transitu*, the passages between the shops, the yards, and the principal shops are traversed by tramways, with turn-tables at the intersections.

In the consecutive processes of manufacture the pattern maker takes precedence; and it will be seen that the pattern shop is within easy reach of the brass and iron foundries, to which the pattern maker's work leads up. The pattern shop, a large rectangular building, is the only one in the works of three storeys. The basement is a store room, the principal floor a turnery, and the first floor a pattern shop, with pattern stores in the roof. There is a second pattern makers' shop above the larger turnery. These shops present a brighter and a more attractive aspect than some of the others, being free from clangour, and extremely interesting from the careful exactitude of the work done. Adjoining the large pattern shop is a spacious wood-working shop, and covered timber stores, the latter containing valuable stocks of mahogany for the casing of cylinders, and of lignum vitæ for screw-propeller tubes. The carpenters' shop is well supplied with saw benches, planing machines, and other wood-working tools. The

pattern stores are vast and varied in their contents, being an accumulation of all the patterns produced by the firm since they commenced to make marine engines. A catalogue of these would be a valuable contribution to the technical history of steam navigation.

The smiths' shop is on a large scale, and contains as many as sixty fires. These are served by a powerful blast worked by the engine, and are fitted with tuyères of the most improved kind. This shop is furnished with one machine for shaping hot metal, and another for sawing hot bars. It is supplied with cranes and five steam hammers, equal to dealing with such forgings as are turned out, none of them being of extraordinary weight.

The foundry is also another weird temple of Vulcan, in which much of the work done is upon a large scale. There are four cupolas for iron; the pots for the largest castings containing 15 tons each. This part of the works is served by five cranes, made by the firm, that are capable of lifting or lowering 50 tons each. They are so placed as to command the whole area of the foundry. In the course of a week 150 tons of metal are occasionally run. Attached to the foundry is a department for brasswork, with furnaces for running brass and gun-metal.



Sketch-Plan of Penn and Sons' Establishment.

The castings in this department also are occasionally very heavy. The gun-metal bosses for some of the larger screw propellers, into which the blades are fixed, weigh, in some instances, as much as 7 and 8 tons, and the blades more than 5 tons each. The screw-shaft tube is also of gun-metal, and in some cases reaches to 30 feet in length, the annular thickness being about 2 inches; these are not, in the category of brass-foundry, "small work." The screw-shaft tubes are the invention of Mr. John Penn. They are cast with dove-tailed grooves, that are fitted with bars of lignum vitæ, upon which the shaft revolves. This hard, oleaginous wood is found to furnish an excellent and durable bearing.

The smaller turnery, a long and comparatively narrow shop, is an interesting department, containing many excellent machine tools, in lathes, planing, slotting, shaping, screw-cutting, drilling machines, &c. Among the other curiosities in tools is the so-called "Jack-in-the-box" planing machine. The distinctive peculiarity of this invention is, that the cutter reverses, and attacks the metal as it travels in each direction. The cut is about a third of the width of an inch tool. A machine in the same shop is specially designed for radial cutting; and can

take work of as much as 13 feet radius, in sections of about 5 feet. This shop has shafting in motion from end to end along each side, and, as in all the other shops where heavy weights of metal have to be moved, is abundantly supplied with well-placed, powerful cranes. Here one of the smallest of engines was made; it was of 8 horse-power, with a 9-inch cylinder and 10-inch stroke, and was for one of the somewhat unpopular craft known as steam launches. In strong contrast with this tiny machine are the engines that are building in the works, or that have been built for the *Encounter* frigate, the *Black Prince, Achilles, Minotaur, Northumberland, Hercules, Sultan, Devastation,* and the *Northampton;* for the *Kaiser, Deutschland, Independencia,* and many others, ordered by our own and foreign governments, some of these engines being capable of working up to 8,500 horse-power.

The destination of the greater part of the work done in the various departments is the erecting shop, where the masses of metal are to be brought into shape, and put together. This great room is grand rather than picturesque. It has a roof in four bays and a lay-to. The height to the gutters is about 35 feet. The roof, which is of iron, has on each side of the ridges broad belts of glass, which amply light the great area, that has dimensions, in round numbers, of about 180 feet by 150 feet. The roof is supported upon ranges of strongly-strutted wooden uprights. The structure was erected over another fitting shop, that was not unroofed before the new one was ready to cover the space. In this shop great weights have to be moved in various directions, and it is, accordingly, well supplied with machinery and apparatus to meet this need. It has two lines of tramway that communicate with the foundry, smithy, and other parts of the premises. It has numerous steam and hand swing cranes, and twenty overhead travelling cranes, each of which can transport any mass for which it is equal, from one point to another, within their own bays respectively. The tramway facilitates change of place, when required, from one bay to another. Many of the most remarkable machine tools in Messrs. Penn's works are to be seen in this shop. Some of these exercise great power, others are delicate in action; some are eccentric, others direct; but whether eccentric or direct, they are uniformly precise in their operation. Not a few of these machine tools are by the most noted makers, but the best in the works for special purposes have been designed by members of the firm, or by men connected with it, and are not protected by patent.

The sights and sounds with which he is assailed in such a great Cyclopean workshop as this, are somewhat distracting to the unprofessional visitor. All around him is dead matter—to use a solecism—in a state of activity, matter dead in itself, but quickened and controlled by human intelligence. Extraordinary tools for such extraordinary operations as are carried on here may be naturally expected, and the expectation is not disappointed.

Sacrifice of height in the engines of ships of war, so as to bring them low in the hull, necessitated either diminished stroke and loss of power, or the introduction of cylinders of much enlarged diameter. The manufacture of the double-trunk engines necessitated new tools, new modes of working, enlarged plant, and, generally, means and appliances for working large as well as smaller masses of metal with precision and rapidity. The visitor cannot fail to be impressed by the enormous weights of metal he sees in all directions; arms of engine-frames weighing 27 tons each; crank-axles weighing 34 tons as they come from the forge; cylinders of 12 feet diameter; bosses, blades and tubes, of gun-metal for screw propellers, weighing in all nearly 40 tons; with other parts in like proportions. Nor can he fail to be struck by the correspondingly vast dimensions of the machine tools that have been invented to bring these masses of metal into exact form, and by their majestic performances. The successively improved forms of marine engine introduced by Messrs. Penn—the oscillating, the double-trunk, the compound, and, last, the "John Penn and Sons' three-cylinder compound expansive engine"—have from time to time stimulated to the production of new tools with extraordinary powers, and to the adoption of methods of manipulation before undreamt of. Amongst these wonderful machines there is a lathe with a chuck to take work of 12 feet in diameter. By adjustment of the straps upon the different cones, and other means, eight different speeds can be given to the machine; the larger the diameter of the work, the less the speed attained. A planing machine in the shop would have for its maximum work a job 8 feet wide, 8 feet high, and 18 feet long. A boring mill, designed and constructed by the firm, produces a true internal surface upon cylinders of 12 feet diameter.

A principle that has been kept in view by Messrs. Penn, in the construction of their engines

—maximum results from minimum weight and exercise of power in attaining them—is illustrated in some of their new machine tools. So it is with their vertical planing machines, in which the ordinary method is reversed. In these tools the work remains stationary, and the cutter moves—Mahomet is brought to the mountain, not the mountain to Mahomet. A boring machine for drilling the tube-plates of condensers is also a very clever tool. The best possible machinery for this work is obviously of the utmost importance, from its quantity. Some of the large engines produced by Messrs. Penn have in the condensers 7,000 tubes, aggregating 20 miles in length. The most remarkable machine in this theatre of mechanical wonders is one that has been invented and made by the firm for dressing crank-axles. These are the heaviest forgings, and are the most unwieldy and awkward in form of any that have to be dealt with. By alterations in the gearing of the machine in question, it performs the several operations of planing each side of the jaws of the crank, the faces, the segmental crown, and turns the crank-pin. The three-throw crank-axles are in sections, connected by flanges and bolts so as to be equal in strength to the ponderous and unmanageable single piece.

Among the engines that have been or are being made, are four pairs for twin-screws of 500 horse-power nominal, for the *Ajax* and *Agamemnon*, and four pairs of equal power for the Italian Government. Three-cylinder compound expansive engines have been completed for the *Northampton*, R.N., and tried with great success. They are an entirely new type. The cylinders are 54 inches diameter, 3 feet 3 inches stroke, and make about 85 revolutions at full power. The great advantages claimed for this form of engine are, that it can be used as a compound engine for moderate power—say, a third to half of the maximum power—by using one cylinder at high pressure, and the other two at low pressure. When a high power or speed is required, the steam can be admitted direct from the boilers into all the three cylinders; the highest power required will thus be attained, at a small sacrifice of economy. The indicated horse-power of these new engines is 6,000 working as expansive, 3,000 working as compound; the nominal horse-power being 1,000. The great erecting shop is heated by hot-water pipes.

The engine works and yards have an area of about seven acres. The average number of men employed is about 1,200, including a few youths and gentlemen-student apprentices, from various parts of the world. The power exercised by the thews and sinews of the host of workmen is ministered to by three pairs of very compact and beautiful engines, made in the works, that are of 24 horse-power nominal per pair, but capable of working to double that power. They are placed in the situations where the power is needed, and where it can be most completely utilised.

At the boiler works on the Thames bank about 500 men are employed. Here, as at the "upper shop," the appliances for the various processes are the best of their kind, including machines for straightening or bending iron plates, and a rolling machine, with remarkably effective gear, that makes excellent work in rolling half-inch plates 12 feet long. The rivet-making and riveting machines are also very clever, and do their work with wonderful rapidity and completeness. This department is impressive by its deafening noise; and among the objects exciting observation are the vast dimensions of the boilers for some of the great war ships that are in progress. An engine of 30 horse-power nominal serves the works.

There is telegraphic communication between the upper and lower shops, and between each and Mr. Penn's residence at the Cedars. There is also communication between the two shops—which are about a mile apart—by traction engines that travel during the night, and in daytime by wagons and trucks drawn by teams that are unsurpassed for power and symmetry in the county of Kent. It is a saying of Mr. John Penn, that he has always tried to get the best horses and the best men procurable. He has been very successful as regards the horses, and fairly so as regards men, but he states his experience to be that "it is easier to arrive at a satisfactory conclusion on the points and qualities of a horse than of a man." It says much for the relations between masters and men in Penn's works, that no employment is more eagerly desired by mechanical engineers or boiler makers in the district than "a job at Penn's." The liberality of the firm is greatly to their honour. Their numerous and generous Christmas gifts are alike creditable to donors and receivers. On the occasion of my visit, I fell upon an "old man eloquent," long in the employment of the firm, who, without "pumping" on my part, was earnest and garrulous in laudation of the "masters." I am afraid to quot him as to the numbers and amounts of life-pensions to "old hands" with which the firm charges itself, or concerning the

number of widows that Mrs. John Penn, of the Cedars—a true "Lady Bountiful"—has upon her books. The old man capped his details by the climax, "In fact, master, there's nobody like them!" From all that we have learned from other sources, we conclude that the sad wranglings and contests often prevailing between capital and labour would be almost impossible if large employers, acting upon its suggestions, would take a leaf from the book of John Penn and Son.

In fine, the high reputation of the firm, and the confidence reposed in it by our own and foreign Governments, are attributable to the signal ability of its members, and their persevering action upon Mr. John Penn's own declaration—"I can't afford to turn out second-rate work."

COTTON.—II.

INDIAN MUSLINS—ENGLISH COMPETITION—EARLY SPINNING MACHINES.

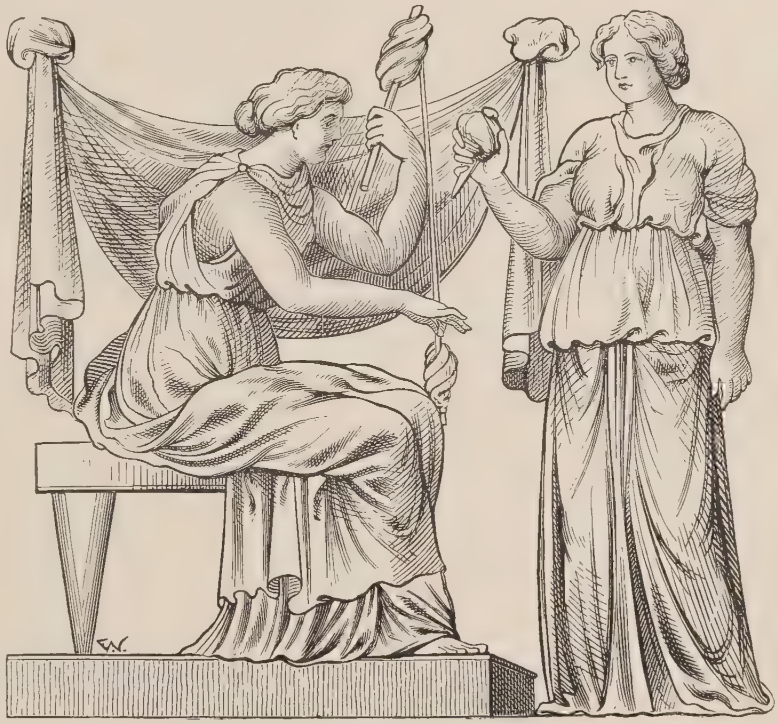
By David Bremner, Author of "The Industries of Scotland."

TOWARDS the end of the seventeenth century Indian silks, muslins, and printed calicoes became fashionable articles of dress with the upper and middle classes in this country. In consequence of this, persons interested in home manufactures were loud in their complaints, and there were not wanting prophets who foretold all sorts of calamities if people persisted in wearing the products of Hindoo looms in preference to home-made fabrics. The author of an essay upon trade, entitled "The Naked Truth," published in 1696, made the following reflections on the obnoxious fashion:—"The advantage of the East India Company is chiefly in their muslin and Indian silks (a great value of these commodities being comprehended in a small bulk), and those are becoming the general wear in England. Fashion is truly termed a witch—the dearer and scarcer any commodity, the more the mode. Thirty shillings a yard, and only the shadow of a commodity when procured!" And Gibson, in his "History of Glasgow," thus complains of the manner in which the Indian fabrics were sought after:—"While the industrious inhabitants of Glasgow and Paisley were lately exerting themselves to improve, bring to perfection, and extend the manufactures of cambric and lawn (flax fabrics), the greater part of the women in Scotland were wearing muslin, a fabric of India; nay, so great is the influence of fashion, that the very wives and daughters of these men were wearing this exotic themselves. Surely we are void of thought!" About the time this was written, a proposal was seriously made that a patriotic association should be formed for the discouragement of the fashion of wearing Indian cotton cloths. Ladies who should persist in the practice were to be shunned as enemies of their country, and gentlemen who associated with such ladies were to be held in scorn. As such an organisation would interfere with the liberty of the fair sex, it was not proceeded with. A good deal of ridicule was heaped upon the preservers of the freedom of female action in this case, and several writers addressed themselves to proving that "the liberty of the ladies, their passion for their fashion, had been frequently injurious to the manufactures of England."

In the year 1700 an Act was passed forbidding the importation of Indian silks and printed calicoes, under a penalty of £200. This did not, however, check the desire of the wealthy classes to obtain the forbidden articles, and an extensive system of smuggling sprang up, for the suppression of which further enactments had to be devised. Daniel Defoe, in his *Weekly Review* for the spring months of 1708, congratulates Parliament on the action taken to preserve our native industries, and thus describes the state of matters which had previously existed:—"We saw our persons of quality dressed in Indian carpets, which, but a few years before, their chambermaids would have thought too ordinary for them; the chintzes were advanced from lying on their floors to their backs, from the foot-cloth to the petticoat, and even the Queen herself at that time was pleased to appear in China and Japan—I mean China silks and calico; nor was this all, but it crept into our houses, our closets, and bed-chambers; curtains, cushions, chairs, and at last beds themselves were nothing but calicoes or Indian stuffs, and, in short, almost everything that used to be made of wool or silk, relating either to the dress of the women or the furniture of our houses, was supplied by the Indian trade. What remained, then, for our people to do but to stand still and look on, see the bread taken out of their mouths, and the East India trade carry away the whole employment of the people? What had the masters to do but to dismiss their journeymen, and take no more apprentices?

What had the journeymen to do but to sit still, grow poor, run away, and starve?"

In defiance of the prohibitory laws, and the pamphlets of patriotic protectionists, the importation of dress materials from India continued, and they were generally preferred to the native products. The English spinner and weaver were equal only to making coarse fabrics, and Manchester, Bolton, and Leigh, could offer no finer cloths than those known as dimities, jeans, velveteens, fustians, fancy cords, and the like. It was only natural then that the women of the time, once having possession of garments made of the light and elegant cloths of India, should give those a preference over the heavy and plain-looking home-made stuffs. In order to meet the popular taste, both spinners and weavers did their best to rival the Hindoo manufacturers; but for a long time they met with but little success, for their appliances, though quite equal to those of the Eastern workers, were not guided by the hereditary skill of thousands of years.



Ancient Distaff Spinners. *(From Montfaucon.)*

Ingenious men had, however, for some time been directing their attention to the subject of improving and extending the home manufacture of cotton by means of machines which would excel hand-labour in both the quality and the quantity of work done. They succeeded marvellously, and many machines were devised which, in a comparatively short time, had the effect of revolutionising the cotton manufacture, and laying the foundation in England of her greatest industry. Under the old conditions of production the manufacture made very slow progress, as is exemplified by the fact that during the first half of last century our imports of cotton-wool did not exceed in any year 2,000,000 lb., of which a considerable proportion was devoted to the making of candle-wicks. But, after all, it is not strictly correct to speak of the cotton manufacture as existing in England in those days; for in no fabric was cotton-warp used, and the linen-warp was really the more important part of the cloth produced. It was not until the year 1773, when Arkwright had introduced his spinning machine, that a piece of cloth composed entirely of cotton was made in this country. The system on which the trade was carried on was this:—The merchant supplied the weaver with linen-yarn for warp and a quantity of cotton-wool sufficient to produce the weft. If the weaver had no family who could spin the latter for him, he had to give out the work to be done, and lost much time in going from house to house to find assistance. It was no unusual thing for a weaver to walk several miles every morning to collect from the spinners the weft he would require to keep him employed during the day. The demand for weft was usually greater than the supply, and as the spinners were constantly hurried, the yarn they produced was of a very irregular quality. Every inducement was held out to spinners to increase the quantity of their work, and their wheels were kept "birring" from early morning till late at night, the tediousness of the toil being lightened by the knowledge that gifts of ribbon or other finery would certainly reward any extraordinary effort on their part. A weaver in those days had no enviable position. When he was supplied with the linen-warp and cotton-wool necessary for the production of a piece of cloth, he was at the same time bound under a penalty to return the finished work by a certain day; and when the custom of stimulating the spinners by means of gifts was established, he found a heavy tax placed upon his labour. The amount of time he had to devote to

running to and fro, first in search of work and then in search of spinners, made it necessary that he should, in order to make a living, spend many hours of the night at his loom. This difficulty in obtaining a supply of yarn retarded the progress of the trade very much; and yet the advance made was such as to excite wonder in some minds, for in the *Daily Advertiser*, in 1739, we read as follows:—"The manufacture of cotton, mixed and plain, is arrived at so great perfection, within these twenty years, that we not only make enough for our own consumption, but supply our colonies, and many of the nations of Europe. The benefits arising from this branch are such as to enable the manufacturers of Manchester to lay out above £30,000 a year for many years past on buildings. 'Tis computed that two thousand new houses have been built in that industrious town within these twenty years." A more exact idea of the extent to which the trade had been developed at this time is to be obtained from the official statistics, which show that the total import of cotton-wool into England was, in the year referred to, considerably under 1,700,000 lb., while the value of the cotton goods exported did not reach £20,000. A good test of the state of the manufacture is also afforded by the returns of imports from Ireland of linen-yarn to be used for warp in the cotton fabrics. They are as follows:—1731, 13,734 cwt.; 1740, 18,519 cwt.; 1750, 22,231 cwt.

We have seen that the chief obstacle to an increase of the cotton manufacture was the want of means of producing yarn in sufficient quantities. Let us now explain how that difficulty was overcome. The twisting of animal and vegetable fibres into threads is an art of the highest antiquity, and must, of course, have had its origin prior to the sister-art of weaving. Of the existence of both at a remote period in the history of the human race we have evidence in the earlier books of the Bible. In the account given, in the 35th chapter of Exodus, of the directions concerning the building of the tabernacle in the wilderness, the people are requested by Moses to bring offerings of "blue, and purple, and scarlet, and fine linen, and goats' hair;" and further on, it is stated that "all the women that were wise-hearted did spin with their hands, and brought that which they had spun, both of blue, and of purple, and of scarlet, and of fine linen." The Egyptians had, it is to be presumed, been familiar with spinning and weaving long before that time, and these and other arts the Hebrews carried with them when they took their departure. Among various nations of antiquity the art of spinning was regarded as a great boon to the human race, and its invention was attributed to a high source. The Egyptians gave the honour to Isis; the Mohammedans to a son of Japhet; the Chinese to the consort of their Emperor Zoro; the Peruvians to the wife of Manco Capac, their first Sovereign; and in some ancient statues of Minerva, the goddess holds a distaff as a token that she was the originator of the art. The distaff and spindle were apparently the earliest appliances used in spinning, and it was not until a comparatively recent period that the spinning-wheel was invented. The use of the spindle and distaff could not be better described than they are by Catullus in the following passage from his poem on the marriage of Peleus and Thetis:—

> "The loaded distaff in the left hand placed,
> With spongy coils of snow-white wool was graced;
> From these the right hand lengthening fibres drew,
> Which into thread 'neath nimble fingers grew.
> At intervals a gentle touch was given,
> By which the twirling whorl was onward driven;
> Then, when the sinking spindle reached the ground,
> The recent thread around its spire was wound,
> Until the clasp, within its nipping cleft,
> Held fast the newly-finished length of weft."

It does not appear that the spinning-wheel was known in this country till the fourteenth century, though a wheel of very simple construction was used by the Hindoos before that time. This early Indian wheel was capable of producing coarse yarns only, and the yarns from which the once famous muslins of Dacca were made were spun on the spindle and distaff, which primitive appliances yet exist in some parts of the East, and were, within this century, not uncommon in English homes. The first form of spinning-wheel known in this country, consisted simply of a spindle which was turned by a cord passing over a broad-rimmed wheel. Having by the use of hand-cards formed the wool into "rolls," the spinner began operations by causing the wheel to revolve by a push of her hand, and then attaching the wool to the spindle, drew it into a soft cord called a "roving." When the spindle was full, it was removed, and a fresh one put on. This process was continued until the supply of wool was worked up, and then came the "drawing" process. A spindleful of roving was placed on the lap of the spinner, and the end of the cord attached to the empty spindle in the wheel. By rotating the machine and pulling out the roving between the finger and thumb of the left hand, the yarn was reduced to the required degree of fineness, and firmly twisted. A serious defect

of the machine was its requiring one hand of the spinner to keep it in motion. This disadvantage was overcome, after the wheel had been in use about two centuries, by fitting it with a crank and treadle motion, which enabled the spinner to work the machine with her foot, while, with both hands free, she was able to produce a much greater quantity of yarn in a given time than she could with the old wheel. The treadle-wheel came largely into use as a domestic machine. The wives and daughters of well-to-do people throughout the country were taught how to work it, and it was, not so long ago, a common thing to hear a thrifty farmer's spouse boast that her household linen and blankets were all of her own spinning; while home-made articles of the same description used to be a highly-treasured part of a daughter's dowry. In many parts of the country the wheel is still to be met with, especially in the Highlands of Scotland and the rural districts of Ireland; indeed, it is on record that the most illustrious lady in the land not only possesses a machine of this kind, but that she and her daughters use it occasionally.

The first attempt to supersede spinning on the wheel is by some authorities attributed to Mr. John Wyatt, of Birmingham. About the year 1730, it is said to have occurred to him that a pair of rollers might be made to perform the part of the finger and thumb of the spinner in supplying the wool-cardings to a mechanically-moved spindle, and he applied himself assiduously to testing the matter. He reached only the verge of a grand discovery, however, and left the prize to be carried off by other hands. One of his sons thus describes the first experiment made with "a spinning-engine without hands":—"In the year 1730, or thereabouts, living then at a village near Litchfield, our respected father first conceived the project, and carried it into effect; and in the year 1733, by a model of about two feet square, in a small building near Sutton Coldfield, without a single witness to the performance, was spun the first thread of cotton ever produced without the intervention of human fingers, he, the inventor, to use his own words, 'being all the time in a pleasing but trembling suspense.' The wool had been carded in the common way, and was passed between two cylinders, from whence the bobbin drew it by means of the twist." Encouraged by this measure of success, Mr. Wyatt sought to turn it to account, and with that view allied himself with an enterprising foreigner named Lewis Paul. The latter, who appears to have had considerable mechanical skill, effected some improvements on the original machine, and in 1738 took out a patent in his own name for spinning wool and cotton by means of rollers. His specification set forth that "the wool or cotton having been prepared by carding into slivers, one end of the mass, rope, thread, or sliver is put betwixt a pair of rowlers, cillinders, or cones, or some such movements, which being twined round by their motion draws in the raw mass of wool or cotton to be spun in proportion to the velocity given to such rowlers, cillinders, or cones. As the prepared mass passes regularly through or betwixt those rowlers, cillinders, or cones, a succession of other rowlers, cillinders, or cones moving proportionably faster than the first draw the rope, thread, or sliver into any degree of fineness which may be required." This is intelligible enough, but the succeeding sentences describe a mechanical impossibility. They are in these words:—"Sometimes these successive rowlers, cillinders, or cones (but not the first) have another rotation besides that which diminishes the thread, yarn, or worsted—viz., that they give it a small degree of twist betwixt each pair by means of the thread itself passing through the axis and center of that rotation. In some other cases only the first pair of rowlers, cillinders, or cones are used, and then the bobbyn, spole, or quill, upon which the thread, yarn, or worsted is spun, is so contrived as to draw faster than the first rowlers, cillinders, or cones give, and in such proportion as the first mass, rope, or sliver is proposed to be diminished."

In the year 1741, Mr. Wyatt and his partner started a small factory at Birmingham for spinning cotton-yarns with the new machine. The establishment must have been on a very limited scale, as it gave employment to only ten girls, and the machinery was kept in motion by two donkeys, which by pulling round a horizontal bar caused a vertical shaft to revolve. Mr. Paul took charge of the factory, and Mr. Wyatt spent his time chiefly among the manufacturers of cotton goods, whom he tried to induce to purchase his machine-made yarns. The quality, however, appears to have been so inferior that he failed to meet with purchasers to a remunerative extent, and after struggling on for a couple of years, the venture was abandoned. Dr. Johnson's friend, Mr. Cave, proprietor of the *Gentleman's Magazine*, had taken some interest in the labours of Mr. Wyatt, and had so much faith in the principle of the apparatus that he established a factory at Northampton, in which he fitted 250 spindles, and employed 50 operatives. The work was persevered with in a most

praiseworthy manner, but with no better success than attended Mr. Wyatt's efforts; and in the course of a few years the factory changed hands, and was ultimately dismantled. Spinning by means of rollers appeared a hopeless project, as after being subjected to various modifications, and being studied by ingenious minds for nearly a quarter of a century, Mr. Wyatt's machine could not be got to produce marketable yarn. Mr. Paul is said to have shown much perseverance in following up the idea of his allowed to pass almost without contradiction until the year 1858, when Mr. Robert Cole, F.S.A., in a paper read at the meeting of the British Association at Leeds, took up the matter, and by indisputable evidence showed that to Paul alone must be awarded the merit and honour of being the sole inventor of the machine for spinning cotton and wool by means of rollers, and that Wyatt had nothing whatever to do with the invention or carrying it into execution beyond the fact that he had advanced some money

THE TREADLE SPINNING-WHEEL.

friend, or rather, as some writers on the subject allege, in trying to turn to his own exclusive profit the invention of one who voluntarily introduced him to the venture. In 1758, on the plea of having effected some improvement, he obtained a second patent for a roller spinning-machine; but it would appear that the apparatus he desired to protect was identical with Mr. Wyatt's original machine.

Though the earlier historians of the cotton manufacture give to Wyatt the credit of being the originator of roller-spinning, and describe his relations with Paul to have been as above narrated, they appear to have had only very slender grounds for doing so. Their statements were, however, to Paul, and had been in his employment for some time as a workman receiving a weekly wage. Mr. Cole obtained possession of numerous letters written by both Paul and Wyatt, of accounts and agreements between them, and also of licenses to use his machine granted by Paul to various persons. In none of these does Wyatt appear even in the character of a partner, and when Paul granted to Wyatt the right to use a certain number of spindles on his principle in consideration of the money advanced by the latter, the agreement set forth that the machinery was "the invention of the said Lewis Paul." Lastly, it appears that Wyatt himself never claimed to be the inventor.

EMINENT MANUFACTURERS.—II.

HENRY BESSEMER, C.E.

By Robert Smiles.

A MAJORITY of scientific men exemplify, more or less completely, the truth of Pope's dictum, that

> " One science only will one genius fit,
> So vast is art, so narrow human wit."

Comparatively short arcs of the circle of the sciences are sufficient for their concentrated powers, whether directed to a department of cosmogony or dynamics, or to the fields of the animal, vegetable, and mineral kingdoms, and their products. Mr. Henry Bessemer seems to be an exception to this rule, if it is a rule. The scope of his pursuits extends over a wide range of the applied sciences, and practical mechanics.

His father was a man of extraordinary powers. He (Antony Bessemer), born in London, was taken by his parents to Holland when in his boyhood. At twenty years of age, he distinguished himself at Haarlem by the erection of pumping-engines, to drain the turf-pits. Before he was twenty-five years of age he was elected a member of the *Académie* at Paris, for improvements in the microscope. The Revolution drove him from France, his escape being effected after he had been summoned to appear before the awe-inspiring Assembly. Returning to London, he achieved distinction by his industry and skill as a type-founder. He was the friend, without rivalry, of the eminent Henry Caslon, after whom he named his son Henry, the subject of this sketch. The elder Bessemer, from the fruits of his industry, purchased a freehold estate at Charlton, in the parish of Hitchin, Hertfordshire, where Henry Bessemer was born on the 19th January, 1813.

Educational means and appliances were greatly inferior then to what they are now. Though young Bessemer had his instruction in the neighbouring town, at probably the best school accessible, it is certain that he did not receive there any special training for after-life. From his boyhood he pursued with ardour, as his favourite amusement, the modelling of buildings, and other objects, in clay. His manual dexterity and taste kept pace with each other; and when the family removed to London, Henry had the honour (aged twenty) of exhibiting at the Royal Academy, Somerset House, a model of St. Luke's Church, Chelsea. He continued to follow the profession of modeller and designer for a time with a fair measure of success. His numerous inventions are, in one sense, of two classes—those which he did not, and those which he did, protect by patent. The Patent Office records have no entry of Mr. Bessemer's name prior to 1838, when he was concerned in an invention for the casting of printing-types. His unprotected inventions date from about 1834, when he was twenty-one years of age. These may be referred to irrespective of chronological order; they belong, indeed, to a period not exceeding three years.

The attention of the young inventor having been directed to the difficulty of obtaining good examples

of figured Utrecht velvet, he invented a machine to supply the want. His contrivance proved a success, and part of his productions were used in furnishing some of the State apartments of Windsor Castle. He, moreover, provided many of the designs for figured velvet which are still in use.

About the same time Bessemer put an effectual stop to a fraud which inflicted heavy loss on the revenue. High-priced *adhesive* stamps used frequently to be dishonestly transferred from effete documents to new deeds, and thus made to do duty twice, or oftener, for one payment to the Stamp Office. He invented machinery by which elaborate designs were pierced through the body of the parchment deed, in a manner similar to that now so commonly employed in perforating paper for valentines, &c., and which designs it was impossible to transfer to other deeds. This plan was submitted to Sir Charles Presley at the Stamp Office, and was approved by him and the other Stamp Office authorities; but a second plan of Mr. Bessemer's was, however, preferred, as answering the same important end with less of change in the routine of the office. Mr. Bessemer's second plan was to drill three round holes in all the steel stamp-dies, and fit into them three circular movable steel types, one showing the date of the month, the second the month of the year, and the third the year of issue, so that old stamps thus dated could not be used on a new deed, as its date of issue would betray its former use. This plan met the high approbation of the Stamp Office authorities and of the Ministers of State; and within two months an Act of Parliament was passed, calling in the old stamps, and substituting Bessemer's dated stamps, as they are still in use. Lord Althorp, then Prime Minister, promised Mr. Bessemer a place with light duties, worth £600 or £800 per annum, in the Stamp Office, but he resigned before he had an opportunity of carrying out his pledge, and although the invention has probably saved millions of pounds to the State, the inventor has never received a shilling in acknowledgment of his services. In 1834, Mr. Bessemer was successful in depositing, by a process similar to the modern method of electro-plating, a coating of copper upon castings in pewter, or other metal. This was about a year before Jacobi, of St. Petersburg, announced his electrotype process, and six or seven years before Elkington and Mason, of Birmingham, were fairly at work. Mr. Bessemer's specimens were publicly exhibited.

An expert amateur engine-turner and engraver, Mr. Bessemer, when a young man, executed a large quantity of delicate and beautiful designs on steel, engraved with a diamond point, for patent medicine labels. For this work very high prices were paid, and he had as much of it as he could put his hands to. One other invention we must briefly indicate. Having occasion to use a little bronze-powder for the adornment of his sister's album, he was struck by its high price—seven shillings an ounce. He analysed it, and found that the intrinsic value of the materials was about 1s. per lb., and that the high price arose from the tedious and costly method of preparing it by hand. Many experiments resulted in his contrivance of five self-acting machines, that performed perfectly and rapidly the work hitherto done by hand. To prevent the discovery of his method, he had the machines made in parts by several different engineers. Two workmen, whom he had taken into his confidence, faithfully guarded the secret, and at the end of many years had the large and profitable business of the bronze-powder and gold paint factory at Camden Town handed over to them. Mr. Bessemer, subsequently, in 1843 and 1844, took patents for the manufacture of bronze-powder and gold paint. The result of these inventions has been to reduce the wholesale price of bronze-powder from £5 5s. to 3s. 6d. per pound.

Details, even of the short titles of Mr. Bessemer's patents, would greatly outrun our space. Between 1838 and 1875 inclusive, they are 113 in number, and the numerous drawings that make up seven thick volumes are all his own work. The record indicates a degree of mental activity and versatility, as a keen observer, original thinker, and clever inventor, rarely, if ever, equalled. The subjects include, among others, patents in connection with railway working, improvements in rails, brakes, engines and carriages, axles, wheels, tyres, &c. For improvements in sugar manufacture, and treating saccharine matter, he took fifteen patents. In connection with motors, atmospheric propulsion, rotary air and steam-engine blast-furnaces, hydraulic apparatus, and hydrostatic press for treatment of ores and pig-iron; manufacture of iron and cast steel, and the laminating, shaping, pressing, rolling, moulding, embossing, shearing, and cutting of metals, he took out many patents. He took numerous patents for marine artillery—ordnance, projectiles, and ammunition; screw propeller; anchors; armour-plates; improvements in steam and sailing vessels, and suspended saloons; silvering glass; casting type; bronze and metallic powder, gold-paint, oils, varnishes, ornamenting surfaces with bronze, &c.;

raising and forcing, and collecting and storing water; asphalte pavements; waterproof fabrics; reflectors, lenses, &c.; besides buildings, machinery, and apparatus for a variety of purposes that we cannot stay to enumerate. In two consecutive years Mr. Bessemer took out twenty-seven patents; in some instances, four and five for the most diverse subjects in a single day. For improvements in the manufacture of sugar, he was awarded the gold medal given by the late Prince Consort. He extracted 85 per cent. of juice from the cane. Mr. Scott Russell came next, but fell short by about 10 per cent., although he used a very powerful press.

The famous "Bessemer" steamer, with suspended saloon, was meant to carry passengers over a rough sea so smoothly that they could not by any chance get sick, but it has never yet been fairly tested at sea. The fault that was noticeable in the trial lay not, as far as could be gathered from the passage trips, in the saloon, but in other parts of the ship which were tried and found to be unsatisfactory, and for which Mr. Bessemer could not be held responsible. Mr. Bessemer's grandest invention is the method of "manufacture of iron and steel, without fuel," announced at the meeting of the British Association, at Cheltenham, in 1856, to the admiration and amazement of the scientific world. It should be mentioned that many of Mr. Bessemer's patents are for improvements upon his own inventions, experience having taught him the necessity of blocking pirates at every step.

The rapid conversion of crude pig-iron into malleable iron and steel is the invention, of all others, with which his name will from henceforth be associated. His name is, indeed, inseparably connected with the process and product, and "Bessemer steel" is now known throughout the civilised world. By this process the price of steel rails for roads has been reduced to that formerly paid for iron, and steel tyres for wheels have been reduced from £90 to £13 per ton. The invention was rapidly adopted wherever the iron-manufacture is prosecuted, and many honours have been conferred on the inventor. In England, he received from the Institution of Civil Engineers the Telford Gold Medal; from the Society of Arts, the Albert Gold Medal. He was elected an honorary member for the Iron Board of Sweden; was made a freeman of the City of Hamburg; was made a G.C. of the Order of H.I.M. Francis Joseph of Austria. The late Emperor Louis Napoleon wished to confer on him the Grand Cross of the Legion of Honour, but permission was refused to wear it in this country, and his Majesty presented him instead with a splendid gold medal. In the United States Mr. Bessemer's name will be had in remembrance from its having been given to a prosperous and rapidly increasing town. He also received a gold medal, accompanied by an autograph letter, from the King of Wurtemburg; as well as a gold medal and honorary membership of the Society of Arts and Manufactures at Berlin, &c. And in January, 1878, the Institution of Civil Engineers have further marked their appreciation of Mr. Bessemer's inventions by conferring on him the honorary title of C.E., and have also awarded him the splendid Howard Quinquennial Prize for his improvements in the manufacture of steel.

Mr. Bessemer's constructive skill and exquisite taste as an architect are admirably illustrated in his mansion at Denmark Hill, and notably by the inner hall, billiard-room, and conservatory, that are simply perfect in their principles of construction, proportions, and the elaboration and graceful beauty of their decorations.

No one who has enjoyed the privilege of intercourse with Mr. Bessemer can have failed to be charmed with his manners and conversation; and any one who can begrudge him such rewards as have been achieved by the industrious exercise of his high talents has a disposition the reverse of enviable.

Mr. Bessemer's life of leisure is not a life of idleness. He is nothing if not inventive and progressive. His last work, for the present, is to design and personally superintend the construction of an observatory for astronomical purposes. The speculum of his telescope will be fifty inches in diameter, of polished plate glass two inches thick, turned on the face by diamond points, in a lathe designed by himself. The depression will be about half an inch. The concave face, after polishing, will be coated with a deposit of pure silver, reflecting 90 per cent. of the incident light. He expects that his instrument will be of equal power to the world-famed telescope of Lord Rosse, whose reflector is an alloy of copper and tin, reflecting only 63 per cent. of the light falling on it.

In closing this necessarily brief sketch, full of facts and suggestions as the subject is, we have to say unfeignedly that "the half hath not been told," and thus abruptly must we take leave of this "great captain of modern civilisation."

Our portrait of Mr. Bessemer is taken from a photograph by the London Stereoscopic Company.

INDUSTRIAL LEGISLATION.—II.

By James Henderson, one of H.M. Assistant-Inspectors of Factories.

SIR ROBERT PEEL—grandfather of the present baronet—who was himself a large employer of factory children, and therefore well qualified to understand their circumstances and condition, was their first prominent champion in the House of Commons. In the year 1802, he succeeded in inducing Parliament to pass a Bill, the preamble of which set forth that, "Whereas it hath of late become a practice in cotton and woollen mills, and in cotton and woollen factories, to employ a great number of male and female apprentices and other persons in the same building; and in consequence of which certain regulations are become necessary to preserve the health and morals of such apprentices and other persons; be it therefore enacted," &c. The clauses of this Act of themselves convey some idea of the condition of the factory operatives at this time, by indicating the evils which it was intended to guard against. It provided—

1. For the washing with quicklime and water, twice a year, of all the rooms and apartments in a mill or factory, and for their due ventilation.

2. That every apprentice should be supplied with two complete suits of clothing, with suitable linen, stockings, hats, and shoes, one new complete suit being delivered to such apprentice once at least in every year.

3. That no apprentice after the 1st of January, 1803, should be allowed or compelled to work more than twelve hours a day, nor before six o'clock in the morning nor after nine o'clock at night.

4. That every apprentice should be instructed in some part of every working day, for the first four years at least of his or her apprenticeship, in reading, writing, and arithmetic, or either of them, according to the age and abilities of such apprentice, "by some discreet and proper person."

5. That the male and female apprentices should be provided with separate and distinct sleeping apartments, and that not more than two apprentices should be allowed to sleep in one bed.

6. That every apprentice should be instructed on Sundays in the principles of the Christian religion, and should attend divine worship once a month at least.

7. That the justices of the peace in Quarter Sessions should be authorised to appoint visitors of factories, whose duty it would be to enforce the provisions of this Act. One of these visitors, it was provided, should be a justice of the peace, and the other a clergyman, either of the Church of England or of the Church of Scotland.

Among other duties which the visitors were called upon to discharge under this Act, was to ascertain whether any infectious disorder prevailed among the operatives in a mill or factory, and they were empowered to call in a physician or other qualified medical practitioner.

This Act of 1802 was therefore the first Factory Act placed on the statute-book. In its operation it was limited in several important respects, otherwise it would certainly have met with a greater amount of opposition than it appears to have done. Its application was limited to cotton and woollen factories, and to children and young persons *who were apprentices* employed therein. Its main defect, however, consisted in the imperfect nature of the machinery by which it was proposed to be enforced. It was too much to hope or to expect that a justice of the peace and a clergyman would willingly undertake such disagreeable and inquisitorial duties as were imposed upon the visitors to be appointed under the Act. Practically the law proved inoperative, and its chief influence was to induce mill-owners to abandon the system of apprenticeship. It was an important Act, however, as expressing the principle that the State was justified in interfering with and regulating labour. In this respect it established a precedent of great value, for although the Act, being limited in its application to apprentices, could hardly be said to raise the question of the right of the State to interfere with the free labourer, yet it unquestionably made the subsequent protection of children and young persons who were not apprentices a much easier matter.

This, the first of our factory-laws, however, was not long in being superseded by the altered conditions of employment in the textile manufacturing districts. Watt's improvements upon the steam-engino revolutionised the trade by substituting steam for water power. It became no longer necessary to build factories in remote and comparatively inaccessible localities, for a steam-engine could be erected anywhere, and more conveniently as a rule in a town than in the country. Manufacturers were not long in discovering that it was much more

convenient and economical to bring the factory to the work-people than to take the work-people to the factory, and mills were rapidly erected in the densest centres of the population. The system of apprenticeship soon became to a large extent obsolete, and thousands of young children were employed in factories who resided with their parents and were altogether controlled by them. Not being formally apprenticed, these children did not come within the scope of the Factory Act of 1802, and did not even enjoy the partial protection which it afforded. The grievous oppression from which they suffered soon raised a loud outcry, and an active agitation was entered upon for an extension of the scope and application of the law regulating the employment of factory apprentices.

In June, 1815, Sir Robert Peel gave effect to this opinion by introducing a new Factory Bill into the House of Commons which would apply to all children employed in cotton-mills, whether apprenticed or not. The hon. baronet explained that what he was disposed to recommend was that a regulation should be adopted forbidding altogether the employment of children under ten years of age, and limiting the hours of work in the case of those above that age to twelve hours and a half per day, including the time for education and meals. This would leave ten hours a day for laborious employment. The remissness of the inspectors under the Act of 1802 in the performance of their duties was referred to by Sir Robert, and he proposed some amendments in this respect. As it was understood that this Bill would not be pressed during the current session, its introduction did not provoke much comment. On the whole, it may be said to have been favourably received. Mr. Horner, in supporting it, said that the practice of apprenticing parish children in distant manufactories was as repugnant to humanity as any practice which had ever been suffered to exist by the negligence of the Legislature. The abuses which the system had engendered were most scandalous, as Mr. Horner explained. "It had been known," he said, "that with a bankrupt's effects a gang of these children had been publicly advertised and put up for sale as part of the property." A most atrocious instance had been brought before the Court of King's Bench about two years before this time, in which a number of boys apprenticed by a parish in London to one manufacturer had been transferred to another, and had been found by some benevolent persons in a state of absolute famine. "Another case even more horrible," Mr. Horner continued to explain, "had come to his knowledge while sitting on a Select Committee. A London parish had actually entered into a formal agreement with a Lancashire manufacturer by which it was stipulated that with every twenty sound children sent to the latter one idiot should be taken."

Beyond the introduction of the Bill nothing more was done in Parliament during the session of 1815. The following year the first Select Committee which considered this important question was appointed, and the facts which were for the first time formally disclosed in evidence materially aided those who were endeavouring to obtain some further legislative protection for the factory-children. The agitation on this subject was concurrent with a widespread revival throughout the country of the interest taken by the benevolent in the social and moral condition of the people. The establishment of Sunday-schools had become very general; and much of the most valuable evidence submitted to the Committee came from gentlemen who had, through these invaluable institutions, become acquainted with the sufferings and degraded condition of the factory-children. Messrs. George and Nathaniel Gould, of Manchester, made some remarkable statements before the Select Committee, their information being in the main derived from their experience in the Sunday-schools.

Another powerful ally the oppressed factory-children found in the well-known social reformer Robert Owen. Owen's opinions upon this question of factory legislation were highly valuable, because he had already put them to the test of practical application at the large mills at Lanark, in Scotland, of which he had been for some years part-owner and manager. He informed the Committee that when he and his partners acquired the Lanark Mills, some seventeen years before, he found five hundred children employed in them, who had been obtained chiefly from the Edinburgh poor-houses. The ages of these children ranged generally from five and six to seven and eight, and their hours of work were thirteen per day, inclusive of meal-times. Owen, with that remarkable conscientiousness that distinguished all his actions in life, had his attention concentrated on the condition of this large number of helpless children, and he soon discovered that, although they were extremely well fed, well clothed, and well lodged, and though great care was taken of them when out of the mills, yet their growth and their minds were materially injured by being employed at these ages in the cotton-mills for eleven hours

and a half a day. It was true, he said, that these children, in consequence of being well fed and clothed and lodged, looked well and healthy to the superficial observer; yet their limbs were very generally deformed, their growth was stunted, and although one of the best school-masters upon the old plan was engaged to instruct them regularly every night, in general they made very little progress, even in learning the common rudiments. Owen submitted to the Committee the heads of a Bill for regulating labour in all factories, which, it is interesting to note, anticipated in some respects the action of the Legislature by nearly half a century. He proposed to prohibit the employment of children under ten years of age altogether; and he was the first to make the suggestion that work and education might be combined. He proposed that from ten to twelve years of age children should only be employed half time in the factory, while required to attend a day-school. Many years afterwards this idea was acted upon by Parliament, and it has proved a remarkable success. For young persons over twelve years of age, Owen was of opinion that ten hours of actual work in the day, or at most ten hours and a half, should be established as a maximum. The difference in the cost of production, supposing these regulations were enforced, he maintained would be but slight, and no party would suffer from them either in respect to our home or foreign trade. Owen's confidence upon this point, however, was shared in by few manufacturers, and a strenuous effort was made to depreciate the value of his evidence before the Select Committee. The broad facts established about the cruel overworking of children, however, could not be gainsayed. It was clearly proved that they were sent to work occasionally at five years of age, frequently at six and seven, and the regular hours of labour varied from thirteen to fifteen. At times they extended to sixteen hours out of the twenty-four—from 5 A.M. till 9 P.M. The only stoppage permitted was for dinner, for which they were usually allowed forty minutes. The work-people took their breakfast and tea by snatches while at their work. In some extreme cases it was stated that the factory engine was run continuously for fourteen hours a day, the operators being compelled to swallow all their food while standing at the spinning-frames. Night-work was very common, and instances were quoted where children were employed in the factories till far on in the Sunday mornings.

Notwithstanding the clear proof given of the existence of many gross abuses, the Legislature moved slowly in the direction of providing a remedy. It was not until the session of 1819 that Sir Robert Peel succeeded in getting the Factory Bill through Parliament which he had introduced into the House of Commons four years previously. And, after all, he had been constrained to accept of amendments which seriously impaired the practical value of the measure. Its application was limited in the first place to cotton-factories only, although the abuses of the factory system existed in every branch of our textile manufactures. There can be little doubt that in thus limiting the scope of the Bill our legislators were actuated by a feeling of jealousy against this comparatively new branch of business—an animus which had been even more distinctly manifested during the preceding century by the imposition of special restrictions and burdens upon the cotton manufacture. There was a heavy tax imposed upon the raw material imported from abroad, and even the manufactured calicoes were subjected in some cases to an excise-duty, so as to discourage their competition with the more highly-prized woollen manufactures of the country. The Act of 1802 was not repealed, however, by that of 1819, and the latter, with all its shortcomings, made an important stride in advance. It forbade the employment of any child in any description of work in a cotton-mill until it had attained the age of nine years, and it limited the hours of work for all under sixteen years of age to twelve per day, to be taken between the hours of 5 A.M. and 9 P.M. Out of this period of twelve hours it also provided that half an hour should be given for breakfast and one hour for dinner, thus limiting the actual working hours to ten and a half per day. Provisions were also made under this Act for improving the sanitary condition of factories and for the publication of an abstract of the law in such a manner as that the work-people would be kept fully informed respecting it.

IRON AND STEEL.—III.

THE BLAST FURNACE: THE FUEL.

By William Dundas Scott-Moncrieff, C.E.

Enough has been said in the two previous papers to enable the reader to understand how important it is to have pure fuel for the production of commercial iron. The finest ores are rendered worthless by the use of bad fuel, and inferior ores, after having been roasted, can be so refined by smelting with charcoal, that the best iron may be obtained from them. In the competition that is taking place among different nations and districts, and between individual producers as well, it has become necessary to look carefully into every source of economy. It can be readily understood that when the amount of the fuel employed is so much in excess of the material produced, as it is in the case of the blast furnace, the saving of it is a matter of paramount importance. The price of labour and the difficulties in the way of obtaining fuel vary so greatly in different parts of the world, that those countries which are most favourably situated in these respects have hitherto been able to overlook to a great extent the loss arising from wasteful appliances. But the advances of others have so equalised the struggle, that if any one country is to maintain a pre-eminence, it must take advantage of every possible means for reducing the cost of production by a saving of its fuel. With regard to the interests of the individual manufacturer, every penny saved is a penny gained: so that his whole success may be said to depend on the same conditions of economical production.

It is not only in the interests of any particular industry that the question of how to save our fuel has acquired its present importance. The original sources of supply of all forms of energy are supposed —and reasonably so—to be subjected to a process of continuous exhaustion; but the process is going on so slowly, and to prevent it is so completely beyond the capacity of human ingenuity, that it must be accepted as inevitable. It is a different matter, however, when we come to deal with magazines of heat and force that have been stored up for us by nature, and for the economical use of which we are directly responsible. Already in this country coal-fields have become exhausted which ought to have remained untouched if economical appliances had been made use of. When the measurement of the coal that remains in Great Britain is given in tons, and the time it is likely to last is stated in years, the prospect of exhaustion seems to be distant enough; but if the unit of measurement be represented in square miles, and the periods of time in centuries, the numbers have a more ominous significance. In America the case is somewhat different: there the quantity of coal, both in the United States and in Canada, is so prodigious that several generations may be permitted to hammer away at it to their hearts' content without materially affecting the result. Yet even there the cost of conveyance renders it necessary to use as little as possible. In this country, on the other hand, the time has already come when every thinking man ought to see the national importance of using all reasonable means for saving our supplies of fuel. The calculations which have been made to show how long our supplies of coal are likely to last are so complicated, on account of the different estimates of the ratio of increase, that they are unsuited for a popular treatise.

It has been estimated that nearly one-tenth of the entire area of Great Britain is made up of the coal-measures, which extend, it is believed, to about 11,859 square miles, and are divided into the two great classes of bituminous, and stone or anthracite coal. The former, it is calculated, occupies about 8,139 square miles, and the latter about 3,720.

The bituminous coals are well known from their being almost exclusively used for household purposes. They may be readily recognised from the way in which they cake during the process of combustion. The next in rank is the splint coal, which is largely used in forging furnaces. It does not cake, like the bituminous coals, but is greatly used where intense heat is necessary, because it does not burn away so rapidly as caking coal. The last is the stone or anthracite coal, which requires very intense heat for its combustion, and for long baffled all attempts to use it for smelting purposes. It is to the iron works at Ystalyfera, and the exertions of Mr. Crane and Mr. Budd, of South Wales, that we are indebted for the use of anthracite coal in blast furnaces. Sir William Fairbairn tells of a visit to the works of the former gentlemen about thirty years ago, when he was shown a specimen of anthracite coal that had been subjected to the temperature of fusion of the minerals in a blast furnace for forty-eight hours, and was only charred to a depth of about

three-quarters of an inch, the interior being quite unaffected. In America, the great iron-districts are dependent upon the same sort of fuel, which has been made available partly by the introduction of the hot blast, and partly by constructing the furnaces so as to increase the temperature.

In other countries, the supplies of coal are much less than in Great Britain and America. In France it is estimated at 1,719 square miles, or 1-118th of the area; in Spain, 3,408 or 1-52nd; in Belgium, 518 square miles, or 1-22nd; British America is supposed to contain 18,000 square miles of coal, 2-9ths of its area; the United States, 133,132 square miles of bituminous coal, or 1-17th of its area; and Pennsylvania, 15,437 miles of anthracite, or 1-3rd of its area.*

It would be somewhat beyond the scope of the present paper to explain the causes of the waste that occurs in almost every case in which fuel is employed, from the domestic hearth to the largest steam boiler; but referring especially to the blast furnace, the reader may be able to form some idea of the waste that was going on forty years ago, before the adoption of the hot blast, which is, after all, but one link in a long chain of possible economy. Supposing all the commercial pig-iron of this country to have been produced without the hot blast, in the year 1857 there would have been a waste of at least 12,000,000 tons of coal in the process of smelting alone. What the accumulated waste would have amounted to since that time it may be left to the reader to imagine. In the process of converting the "pigs" into other forms of commercial iron the gross waste that is going on at present may be taken as greater than at any previous period, and is simply incalculable.

We have said quite enough, however, on the general question, and will now give some account of the different kinds of fuel, and the mode of preparing them. It has already been explained that the finest kinds of iron require to be made from the finest kinds of fuel; and so it comes that charcoal, which is the best in respect of purity, and has the strongest chemical affinities, is invariably employed in the production of the best Swedish brands, which stand pre-eminent in all markets. Every variety of wood is capable of conversion into charcoal, but the kinds that are most generally used are those which, on account of their smaller growth, are unfitted for other purposes; and in order to avoid the expense that would be incurred from replanting, it is usual to employ those kinds which spring readily from the root after cutting. Accordingly, the oak and alder are chiefly employed in this country, because they become as luxuriant as ever after a short term of years. This period, of course, varies with the climate, soil, and locality. In the neighbourhood of extensive forests, where large trees are cheaper they are, of course, employed in preference to the smaller timber. The common method of producing charcoal is by piling up the wood, which has been previously cut into short lengths, and filling in the interstices with the smaller branches. The heap being then covered with clay, earth, or wet charcoal powder, is ignited in such a way that combustion is allowed to go on very slowly, and so as gradually to eliminate the gases that are given off by the high temperature. These gases, when they are condensed, become commercially valuable in the form of pyroligneous acid, which is used, among other things, for producing a coarse kind of vinegar. It is therefore of considerable importance to utilise as far as possible the gaseous products which escape from the wood in the process of its conversion into charcoal. With this object, the wood is often placed in air-tight iron retorts instead of in heaps, as already described; an arrangement that admits of the heat being applied from the outside, and allows the gases to be carried off in iron pipes to the condensing apparatus, where they appear in the form of liquid pyroligneous acid. The charcoal which is used for making gunpowder requires to be freed as much as possible from the volatile products; and so the communication between the retorts and the condensing apparatus has to be cut off when the charcoal is cooling, to prevent it from re-absorbing the gases.

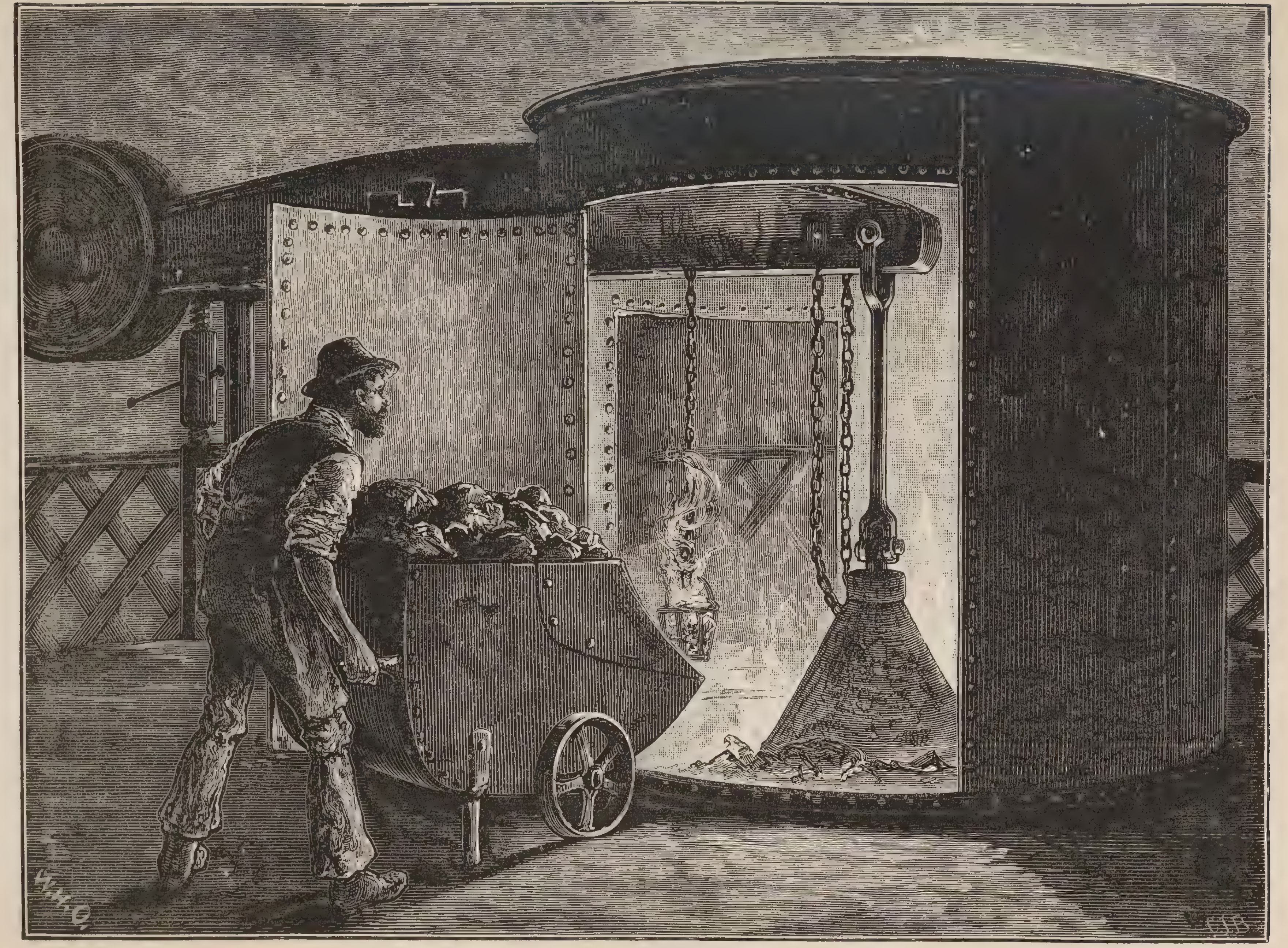
* Taylor.

The following are the results of some experiments on the yield of charcoal from rapid and slow combustion:—

Wood.	Charcoal Produced by Quick Combustion.	Charcoal Produced by Slow Combustion.
Young Oak..................	16·54	25·60
Old Oak	15·91	25·71
Young Deal	14·25	25·25
Old Deal......................	14·05	25·00
Young Fir	16·22	27·72
Old Fir	15·35	24·75
Mean...............	15·38	25·67

These experiments prove the great economy of slow combustion.

It seems quite certain that charcoal was the fuel extensively used for the production of iron in the



Charging a modern Blast Furnace (Govan Iron Works). *(From a Sketch by Mr. W. D. Scott-Moncrieff.)*

primitive processes referred to in the first of these papers; and it also appears that coal was never thought available for the purposes of smelting until it had been subjected to the same process as wood, and been converted into coke. It is somewhat difficult to arrive at any exact information as to the historical sequence of discoveries in the process of smelting iron and casting it into moulds, but it is certainly to this branch of the industry that we owe those improvements in the treatment of coal that render it suitable for the purpose. The difficulties that lay in the way of producing cheap and strong castings led to the discovery of the use of coal in the form of coke, instead of charcoal, which was becoming so expensive, that its employment as fuel rendered the castings unsaleable.

At Greenock, there is a large piece of cast-iron ordnance which is said to have been recovered from one of the wrecks of the Spanish Armada; and if this is an authentic account of its origin, and supposing it to have been manufactured in Spain, it proves the existence of appliances in that country which must have subsequently disappeared. Nearly fifty years previous to the time of the Spanish Armada, about 1543, a certain Ralph Hoge, or Hogge, of Bucksteed, in Sussex, had acquired great reputation for the manufacture of cast-iron ordnance; and "this founder," it is stated, "employed as his assistant Peter Baude, a Frenchman, whom he had probably brought over to teach him the improved method," whatever that may have been. Not long after, a covenanted servant of the Frenchman, John Johnson, excelled his master in the art of casting ordnance; and his son Thomas, in 1595, succeeded in casting forty-two pieces for the Earl of Cumberland, weighing 6,000 lb. or about three tons apiece.

There is no record either of the exact period when the earlier blast bloomary developed into the blast furnace; and it is quite possible that the one had no material influence upon the development of the other, as the earlier apparatus produced little, if anything, but malleable iron, and the blast furnace was exclusively employed for the production of castings. It is certain, however, that the fuel employed up to the middle of the eighteenth century was charcoal only, and that it was the rapid falling off in the supplies of timber that led to the almost total extinction of the industry, which, in the reign of Queen Elizabeth, had risen to the importance of a great export trade. Special enactments had to be enforced for the preservation of the forests; and the production of iron, which had risen towards the end of the seventeenth century to 180,000 tons, was reduced in 1740 to 17,000 tons. It was this pressure, arising from the scarcity of fuel, that became the mother of the recent discoveries and inventions in connection with the iron industries of this country. There is something inexpressibly sad in the biographies of many of the men who were the pioneers of these improvements. They frequently fell as victims to the prejudice and ignorance of commercial Philistines, who looked upon their genius as madness and their improvements as impracticable.

While on the subject of fuel, the story of the early struggles of the original partners of the Colebrookdale Iron Works is of special interest. At another time we shall speak at greater length of Abraham Darby and John Thomas, who founded these works; but at present we shall restrict the story of their lives to their discovery of a cheap substitute for charcoal, which had become so expensive as to threaten to blot out the industry altogether. About 1730, Abraham Darby made experiments upon mixtures of raw coal and charcoal for the production of iron castings, but they completely failed. This led to his conceiving the idea of subjecting coal to the same process as wood when converting it into charcoal, and with this object he arranged a hearth in the open air, upon which he piled a mound of coal, and covering it with clay and cinders, ignited the heap, allowing just sufficient air to be admitted to keep the combustion going on as gradually as possible. The result was a stack of good coke. In applying his newly-discovered material, he himself spent six days and nights on the top of his furnace, taking no regular sleep, and having his meals brought to him; and when at last the experiment succeeded, and the iron began to pour, he fell so fast asleep that his workmen could not waken him. It is said he was taken home a distance of a quarter of a mile in a state of insensibility. In connection with Abraham Darby's venture, there is the somewhat uncommon accompaniment of great success which followed shortly after his first experiment; and it is pleasing to add that the descendants of the two original partners worked together for more than one hundred years, faithful to each other to the last.

The discovery of coke as a substitute for charcoal revolutionised the art of casting in iron, although for long every detail of the process was kept as secret as possible, with barred doors and bolted windows. It was the almost universal substitute for charcoal until the introduction of the hot blast, which rendered the use of raw coal a cheaper and

more practicable mode of obtaining pig-iron from the crude iron. In castings where the pig-iron is poured into moulds, coke is still universally used. The improvements referred to in producing charcoal have been introduced, in a modified form, for converting raw coal into coke: that is to say, that instead of burning it in a heap, as in the case of Abraham Darby's first experiment, it is put into close ovens, by which a great saving is effected, amounting in most cases to fully twenty-five per cent.

In addition to coal, which is now the fuel almost universally employed, it will be well to say something of peat, which is almost the only indigenous source of artificial heat in Ireland and some districts, such as the North of Scotland. In Ireland there are great deposits of iron ore, such as those at the Arigna mines, and the Kidney ores of Balcarry Bay, though they have never become of any great commercial importance, owing to the absence of the fuel necessary for smelting them; but it appears that peat, which is the natural fuel of the country, when dried and carbonised, is peculiarly well adapted for reducing them. Sir William Fairbairn, who was one of the greatest authorities on the subject of iron manufacture, spoke, in 1869, in the most sanguine manner about the prospects of Ireland; but it seems that there are many difficulties in the way of introducing peat as a substitute for coal, on account of its lightness and friability, and also from the expense that must be incurred in drying it and pressing it into a form that is available for the intense temperature of the blast furnace. The author referred to quotes a letter, which he received from Mr. M'All, who had devoted much of his attention to the subject of iron ores in Ireland. He says: "I have sent you two samples of iron ore: one is the red, the other the purple hæmatite. There are strata which are inexhaustible, and the ore can be raised and delivered at the furnace for less than a shilling a ton; the peat or vegetable carbon is equally cheap and abundant. Limestone, of the purest quality, is also close at hand, and can be delivered at the furnace at ninepence per ton. On account of the purity of the materials, iron of the greatest strength and ductility can be made, which, from its non-liability to corrode, would be admirably adapted for marine purposes." The sanguine expectations suggested in this sentence, depending as they do upon the use of peat as a fuel for smelting purposes, have, unfortunately, never been realised. During what is now known as the coal famine, which occurred in 1873, great importance was attached to the use of peat as a substitute for coal, and many experiments were made, on an extensive scale, for drying and compressing it, so as to economise the cost of conveyance and add to its heating qualities, but none of them have survived the test of experience. It is therefore to be feared that until this problem is solved the iron ores of Ireland must remain unremunerative. In speaking of peat, Sir William Fairbairn says that "when it is compressed in hydraulic presses, it loses two-thirds of its volume and two-fifths of its weight through the expulsion of water. It is used for smelting iron in the Vosges, Bavaria, Saxony, and France. The yield of charcoal from peat is never more than 40 per cent.; but the products of distillation are sometimes collected, and form valuable articles of commerce."

It only remains for us to say that the same remarks that apply to the other forms of fuel, with regard to the essential element of purity, apply equally to coal. It is said, whether truly or not, that the famous brands of malleable iron, known as Lowmoor, Farnely, and Bowling, depend for their value and reputation, not so much on the purity of the ores as upon the superior character of the coal with which they are treated. The Lowmoor iron is said to be manufactured from the "Belter bed coal," which contains a smaller percentage of sulphur than any other coal in Staffordshire; but the bed is so thin that Dr. Percy, in his well-known book upon the metallurgy of iron and steel, comes to the conclusion that it is quite insufficient for the manufacture of all the iron that goes out under the famous Lowmoor brand, and he thinks that its superiority really depends upon the care that is taken in every detail of its manufacture. Sufficient has been said, however, to prove that in coal, as well as in all other forms of fuel, freedom from impurities is an essential condition of its value for producing the finest qualities of commercial iron.

The Old Manor-House, Morley, Birth-place of Sir Titus Salt.
(From a Photograph in Balgarnie's "Life of Salt.")

WOOL AND WORSTED.—II.

ALPACA—SECOND PAPER.

SALTAIRE AND ITS FOUNDER.

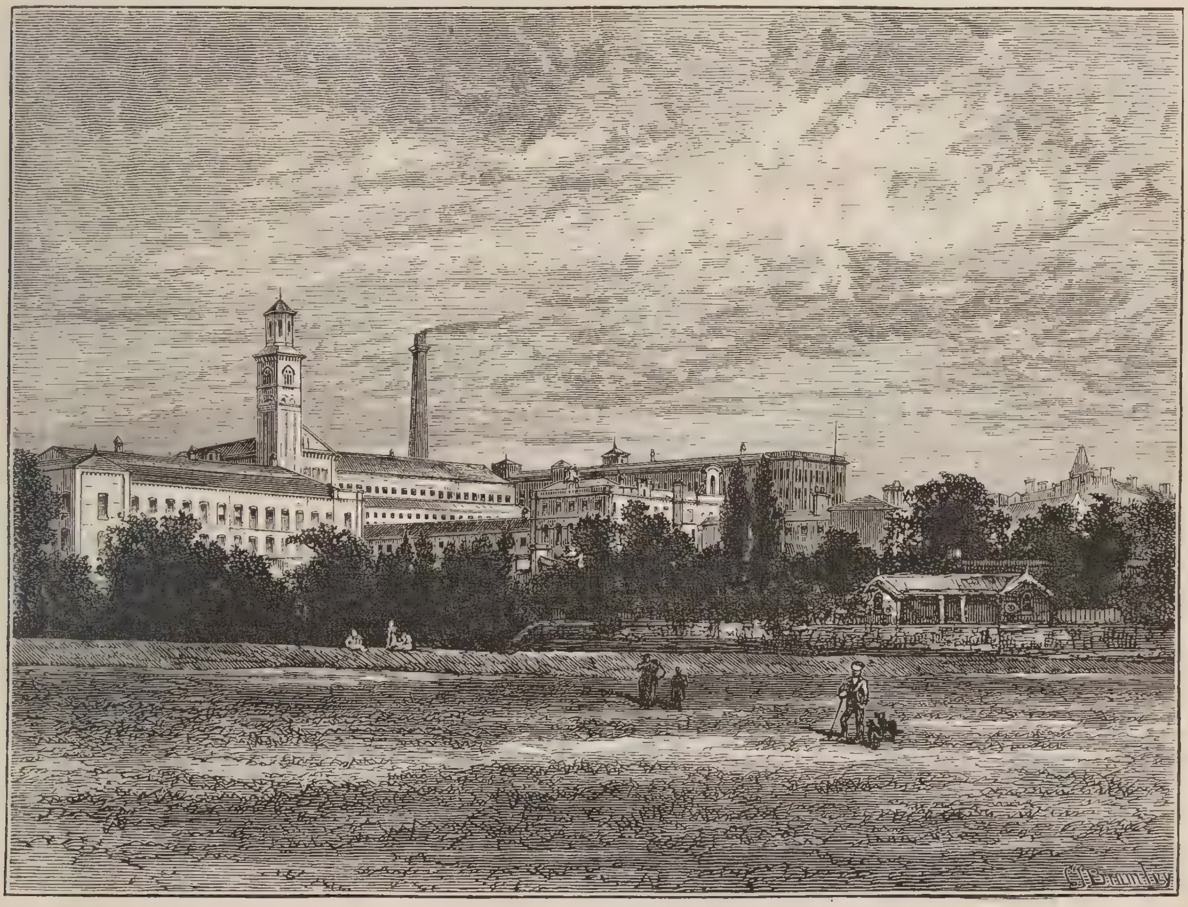
By William Gibson.

WALKING northward from Bradford, the pedestrian has Nab Woods and Heaton Royds on his left, and on the dexter hand rises a ridge that hides all to the north but a fringe of wood and the far-off blue sky. Presently, between three and four miles from the town, the road sweeps over the crest of this barrier, and before him opens out one of the prettiest panoramas in that part of Yorkshire. Lying snugly on the southern ridge, backed by a curtain of green, is a pretty stone-built town, its white houses gleaming in the sun; and lower down the valley there winds the shining Aire, one of the tributaries of the Great Ouse. Beyond that again Shipley sleeps in its cup-like hollow; and away towards the horizon are Baildon, or Baal's Hill, a relic of our Druidical ancestors, and Baildon Moor. To the westward, Bingley nestles among her woods; and up the valley there are the smoke and bustle of Keighley, near the rugged bleakness of that famous country-house where the fiery-hearted authoress of "Shirley" and "Jane Eyre" first saw the light.

This white stone-built town immediately below us is called Saltaire, after its founder, Titus Salt. Three chief buildings in it at once arrest attention —the schools, whose façade and pretty flower-garden in front are nearest; the church, with its fine portico and pretentious cupola, down by the side of the river; and, farther to the right, a huge block of buildings, six storeys high, with a square, bell-like tower, some two hundred and fifty feet in altitude, from whose top curl silently but continuously wreaths of dense smoke. As we stand busily scanning the scene, the clanging of a bell breaks the prevailing silence, the great gates of this building are flung back, and a stream of men and women pours out, and continues to flow on till all the streets of the town are crowded, and one begins to wonder

whether the busy tide of life will ever cease flowing. It is in some senses a remarkable throng that one sees rushing along there. First of all there are an evident neatness and cleanliness about every individual in it, betokening self-respect. Then there is that air of comfort and happiness on the faces never seen on those of the idler and the drone. Murmurs of conversation, intermingled with merry peals of laughter, float towards us on the breeze, and we can see the younger members of the living stream seizing the opportunity of the walk home to indulge in juvenile gambols and good-natured pranks. Not until some four or five thousand persons have filed past us are the great gates shut again, and when each workman composing the throng has closed his own cottage door behind him, one fancies the scene has for awhile been peopled by a dream.

About a quarter of a century ago this thickly-populated town had no existence, and where rows of houses now stand there grew the short green grass. It sprang up, like the palace of Aladdin, under the powerful hand of a good genius, and stands there now a lasting monument to a busy brain and a kind heart. Though both now lie mouldering in that mausoleum beside the church, there is among this people, whom Titus Salt brought together, taught, trained, and benefited, a keen, thankful memory of a great "captain of industry," upon whose like the world may seldom look again. All this is the outcome of a certain journey to Liverpool in the year 1836. It began in Silsbridge Lane, grew through Brick Lane, Union Street, and Fawcett Street mills, till the thriving town of Bradford was too small to contain it, and, bursting the corporate circle, it expanded itself here in pretty Airedale. The first stone in the great alpaca-town of Saltaire was laid by Titus Salt in 1851, and twenty years later the last building was completed.



Saltaire Works. *(From a Photograph by Messrs. Appleton and Co., Bradford.)*

It may not be amiss here to jot down a few particulars concerning the builder of this town. Sir Titus Salt was born at Manor House, near Wakefield, in 1803. Soon afterwards his father removed to Bradford, where he began business as a wool-stapler, and gained considerable notoriety as a keen man of business, and yet honest and clear as the day. When he arrived in the town its population was some sixteen thousand, and its wool industries

were then in their infancy. It was overshadowed by the great town of Leeds, only a few miles distant, and had to struggle to keep pace with its big rival. But there were a few men in the smaller town who were determined to stand by the place of their adoption, and to raise it into a greater position than that occupied even by Leeds itself. Richard Fawcett, Matthew Thompson, the brothers Horsfall, Rand, Garnett, the Ackroyds, and the Salts, father and son, were each hosts in themselves, and before many years had elapsed they held their own with their neighbours. Nor was it long before the great men of Leeds awoke to the fact that they would have to look to their laurels, for, whether as wool merchants or manufacturers, the Bradford men were running them so close that it was doubtful whether after all Leeds was not destined to take the second place in the West Riding of Yorkshire. Young Titus Salt went into his father's business much against his will. Had he had his own way he would have essayed agriculture, for that was his *beau ideal* of a profession. Circumstances, however, were stronger than his inclination, and he had to learn by hard knocks and rude rubs how to buy a pack of wool, and how best to get rid of it to advantage. In his twenty-first year he became a partner in the firm with his father. He was a tall, rather handsome-looking young fellow at this time, and he very soon gained a fair reputation for his business capacities. So when, in 1834, he started for himself as a spinner in Silsbridge Lane, many of his shrewd, kindly neighbours predicted a great future for him. Indeed, about this time, no woolstapler or spinner required any other testimonial than that an applicant for a situation within the West Riding should have been employed by Salt's firm. Being a Radical in politics, young Salt threw himself into the agitations of the Reform movement, and before the Municipal Corporations Act passed he was acting chief-constable of Bradford. On its incorporation, he was at once elected as the senior alderman, a position he held till he was raised to the mayoralty, in 1848. Meanwhile he had been placed on the borough and county benches as a magistrate, and he afterwards rose to be deputy-lieutenant of the West Riding. In the general election of 1851 he was strongly pressed to allow himself to be put in nomination for one of the borough seats, and so far acquiesced as to issue an address to the electors; but he retired before the polling-day rather than split the Liberal vote. He was, however, returned to the Parliament of 1859, but resigned on account of feeble health, in 1861, when Mr. W. E. Forster, himself a manufacturer of great repute, replaced him, and England got its national Education Act. Mr. Salt married, in 1829, Caroline, daughter of George Whitlam, Esq., of Great Grimsby, by whom he had issue seven sons and five daughters, nine of whom survive him; and in 1869 her Majesty the Queen created him a baronet by advice of Mr. Gladstone's Administration. He died—and it is no flattery to say it—full of honours and universally esteemed, on the 29th of December, 1876, almost on the same day that another benevolent and great-hearted pioneer of commerce, Mr. George Moore, of the firm of Moore, Copestake, and Co., of London and Bradford, was called to his rest.

Such, briefly, are the outlines of this remarkable life. Considered from the point of view of a wise philanthropist, he holds possibly the very highest position in the north of England. His purse was ever open to the call of the needy and the friendless. No local or national institution ever appealed to him in vain. He was, however, specially interested in the elementary and higher education of the youth of the district, and his earliest benefactions were bestowed on these objects. At a time when learning was thought to be out of the reach of the poorer classes, he was founding scholarships in the Bradford Grammar Schools for boys and girls, and long before the name of W. E. Forster was connected with the great scheme which became law in 1870, Titus Salt had conceived the idea of founding schools for the children of his work-people, and scientific and other classes for the work-people themselves. Education, indeed, was one of his hobbies, and two of the finest institutions in Saltaire are dedicated to this object.

When, in 1844, his name was very little known outside the circle in which he lived, and the merchants with whom he dealt, her Majesty the Queen, who had heard that the new fabric called alpaca was beginning to come into vogue for ladies' toilettes, and who had a couple of sheep of the alpaca breed in the home farm at Windsor, sent to Bradford two fleeces to be manufactured into his notable cloth. The Queen has always been not only a leader of fashion, but the first to commend virtue and honour wherever they have been brought to her notice, and no doubt Mr. Salt felt highly gratified by royalty taking note of his labours. The fleeces weighed $16\frac{1}{2}$ lb., and when combed and sorted yielded 1 lb. of white and 9 lb. of beautiful black wool. Salt did his utmost to please his illustrious patroness, and he surpassed

himself in the products the wool yielded. He wove an apron, which was a marvel of fineness and glossiness; a striped figured dress, the warp of which was rose-coloured silk, the weft white alpaca, and the flowers thrown up in the pattern alternately in one material and the other. Probably this was the first time in England where the product of the Chinese cocoon and the fleece of the Peruvian mountain camel were brought into contact, and it will serve to show the strides that had been taken in Salt's works, and the progress made in alpaca manufacture since 1836. There was also a plain dress fifteen yards in length, for which only 2½ lb. of alpaca were used. A fourth article was a plaid alpaca dress of the same length, a great novelty in those days, in which the white and black wools and lustres were splendidly blended, and so fine that there was considerable difficulty in telling whether it was not entirely woven of silk. There was also a woollen alpaca dress among the articles sent back to Windsor, so that we may see from these curious facts that Salt by the year 1844 had so extended the processes of preparing and weaving, that he could at will produce the finest and most exquisite materials from alpaca, in combination with cotton, wool, or silk. In eight years, therefore, he had done what all his predecessors had failed in accomplishing. It may be added that these articles so charmed her Majesty that fashions were revolutionised, and the alpaca manufacture received an impetus which carried its staple into the first place among new home products.

Persistence in a course once entered upon was at the root of the success of Titus Salt. He might hesitate long before taking a thing in hand, but once he took it up he never let it go till it had yielded up its secret, and served its purpose. Indeed, it has been said that he frequently worried his architects and machinists to the verge of desperation, for he was satisfied with nothing short of perfection, and pared and polished little defects till they became advantages. With him, indeed, as with nature, there was no such thing as a trifle, and all that left his hands had reached the *ne plus ultra* of finish. This caused his plans sometimes to have the air of slowness; but as soon as he was satisfied with the design, he astonished his subordinates by the eagerness with which he awaited the completed result. Whether in a building, a machine, a new process of manufacture, or a projected variation in some department of his works, nothing he ever took in hand failed, because he brought to it that prime element of success—the doggedness of purpose which would not be denied. In his case, as in that of most great leaders in national industries, what was most characteristic and striking was not so much the amount of genius he brought to bear upon that which engaged his attention, as the amount of vigilance he expended upon it. Then he was essentially a silent man—one after Carlyle's own heart—whose ambition it was not to talk, but to do. He was all his life long a wrestler with nature, and he learned one of her best secrets. She labours silently. Neither the revolution of the spheres nor the growth of a blade of grass are heard, but, for all that, they produce with unerring sureness their appointed results. His habit was to turn a thing over and over in his mind till he had seen it in all its parts; to look into the heart of it till he found what it was capable of doing, and, when he was satisfied that his estimate was right, and that he had thought out its hidden possibilities, to set to work upon it, and make it produce that which nature or art intended by it. One of the dogmas of his creed—and they were comparatively few—was "in the hearts of men, however overgrown they may be by a tangle-work of evil weeds, there is still sympathy with the beautiful and true." And he set himself to find the one and the other everywhere. It will be seen, therefore, that Sir Titus Salt was not only a great industrial captain, a successful manufacturer and merchant, but a social reformer, and moral philanthropist. It may be said that he retired from active life just as his social ideas were realised facts; and his fellow-citizens of Bradford marked their sense of his worth by erecting a statue to him, in 1874, in front of the new Town Hall in Market Street.

Saltaire, the town he reared as the great seat of the alpaca manufacture, covers an area of over 50 acres, and provides accommodation for nearly 5,000 alpaca-workers and their families. It consists of 22 streets, containing 775 houses, besides 45 almshouses for the aged. The streets are wide and regular, the façades of the houses neat, and the interiors fitted up with every accommodation. The baths and wash-houses, which stand about the centre of the town, are a great public convenience. Labouring men know the misery of washing-day in a small cottage; but the inhabitants of Saltaire are free from this domestic plague. There the working man's wife takes her clothes to the public wash-house overnight, and prepares them. Next morning she finds the three steam-engines, with their steam up, ready to drive the washing-machines. When washed, they are transferred to an immense

Cornish boiler, 18 feet by 6, and when they have been rinsed they are placed in the centrifugal wringer, and in a few seconds they are nearly dry. These wringers consist of a huge circular trough, the sides of which are perforated by many holes, and it is made to revolve very rapidly by a shaft driven by steam. The clothes, placed in it quite wet, are driven against the sides of the trough with great force, and cling tighter and tighter as it rushes round, so that the water is squeezed out, escapes by the holes, and is carried away into the sewage-pipes. By this means a tubful of clothes is wrung almost dry in a few seconds, without any labour to the washerwoman. Next, stretching them on "horses," she wheels them into the drying-closet, and in a few hours from starting she brings them home pure and clean, neatly folded and mangled, be the day fair or foul. In the same building are twenty-four hot and cold water baths, for the use of the town, and an excellently fitted Turkish bath, for those who prefer that luxury.

THE SALT STATUE AT BRADFORD.
(From a Photograph by Messrs. Appleton and Co., in Balgarnie's "Life of Salt.")

"Cleanliness is next to godliness" the old saw says, and Titus Salt did not forget the spiritual needs of his people while providing sanitation. Down by the side of the river there stands a fine church in the Italian style of architecture, surmounted by a noble cupola, the interior of which is decorated in the highest style of art. The whole

structure forms one of the finest specimens of this style of architecture in the kingdom, and cost nearly £17,000. The Congregational form of divine worship is celebrated here. At the other end of the town stands the Wesleyan Chapel, opened in 1868; and within an easy walk there are parish churches. An Independent himself, Sir Titus Salt gave freest scope to the religious opinions of his people.

The other public buildings are—the schools, providing accommodation for 750 children, which, besides a well-fitted gymnasium and ample playground, have gardens, where flowers bloom all the year round; the almshouses, constructed for the reception of 60 aged poor, in which, to save the inmates from climbing stairs, the rooms are all arranged on the ground floor; the infirmary for the sick or maimed, with a staff of paid physicians and nurses; the club and institute, with a good library, billiard, bagatelle, card, smoking, and conversation rooms, a liberally-filled chemical and physical laboratory, art, classical, and science schools; a theatre for public lectures, exhibitions, and entertainments; a gymnasium for the lovers of athletics, a drill-shed for the Saltaire Volunteers, and a band-room for the practice of music. Besides these conveniences, there are lavatories and all necessary offices; and a good refreshment-hall near the works, where substantial and wholesome meals are provided at very cheap rates. All the advantages of the club and institute are provided at merely nominal charges. Each inmate of the almshouses has a pension of 7s. 6d. per week—the married couples, who are not separated in their old age, being allowed 5s. extra; and attached to the building is a neat chapel, for the use of the old folks who might not be able to walk so far as the public places of worship. Down by the banks of the river Aire, a plot of ground, 14 acres in extent, was some years ago opened as a public park, partially laid out in gardens, and attached to which are a cricket-field for the youths and men, a croquet-lawn for the ladies, and a bowling-green for lovers of that sport.

Saltaire, in a word, is a tiny industrial cosmos—self-contained, self-supporting, and self-sufficing. Its architect forgot nothing, overlooked neither age nor sex in his plans, and provided for the shelter, comfort, health, recreation, and instruction of all who should become its citizens. Rents are low, taxes moderate, work constant, wages high: it is a sort of working man's paradise. One thing alone is wanting—but that Sir Titus Salt looked upon as an unnecessary luxury, besides a demoralising institution—a public-house. There are cellars in every house, where a man may have his cask of beer; but no place for lolling over a bar, no tap-room in which the drunkard may hide from wife and children. The result is that Saltaire has a low death-rate, little if any crime, and peace and prosperity within its walls. The idea whence it sprang was noble, and the exalted hope with which the immense outlay was undertaken has been completely realised.

Nor have the people for whom the employer and benefactor did so much been ungrateful. They aided in carrying the scheme to perfect success by economy, sobriety, and good behaviour. Few men or women there are ignorant of the masterpieces of English literature. Many are well versed in science, mechanics, and languages. All the children have had a sound elementary, and some of them a liberal higher, education. Sickness is chiefly the result of accident or old age, and in either case there is ample provision made for the needs of all; while the chime of bells in the church cupola sounds constant invitations to a higher spiritual life and nobler aims. Saltaire, indeed, is one of the happiest and sunniest spots in England, and its people have more than once given public utterance to their feelings of gratitude for its founder. But, after all, it is in the hearts of the people that the memory of Sir Titus Salt lies enshrined. To say that they are all "hero-worshippers" in the truest sense is to give them less than their due. So long as one stone of the town stands upon another, or one heart beats in the breast of those who call it home, it must be emphatically said that Sir Titus Salt will need no panegyrist.

HEALTH AND DISEASE IN INDUSTRIAL OCCUPATIONS.—II.

INFANTS, "HALF-TIMERS," AND WORKING MOTHERS.

BY W. GORDON HOGG, M.D., LATE SENIOR PRESIDENT OF THE ROYAL MEDICAL SOCIETY, EDINBURGH.

A GOOD constitution represents the most valuable part of the worker's capital. To the want of this endowment, which gives power to resist sickness, may be ultimately traced most of the special diseases found among the labouring classes. The first few years of life generally determine the

physical well-being of all animals, man included; once give youth a fair start, and it can contend against the destructive agencies of nature with some prospect of success. Let us therefore inquire how the infants of the industrial classes are reared.

It is a charge not unfrequently brought against this section of the community that they pay more attention to the up-bringing of their bull-terrier "pups" than to the welfare of their own offspring. Even though this were true, we must admit that it is not a failing peculiar to the working classes alone. The country gentleman, for example regards his horses and hounds with an anxious eye, and their management often occupies the chief portion of his thoughts and conversation. The clothing and food of his children are frequently to him what the world generally was to the jackdaw on the steeple, "of no concern at all." A mother moving in high society has duties which are too frequently considered superior to the claims of the nursery. She accordingly delegates the care of her infants to a nurse who is supposed to understand and minister to their wants. In truth, the personal interest of all classes, upper and lower, in their infants, is much alike. There is, however, this to be said in excuse of the manual worker: he cannot afford to hire a good nurse, and his wife has often to leave her babe for the purpose of helping to eke out the maintenance of the family. Barring this painful necessity, medical men who practice amongst the poor will readily testify that their children are the objects of more direct personal parental care than, as a rule, are the children of the aristocracy.

But, unfortunately, when married women are engaged in employments which necessitate absence from home during a great part of the day, their babies must be left in charge of a "care-taker." This habit is doubtless attended with the most disastrous results, as may be shown by citing the great infant mortality in industrial centres where the custom prevails. In all England and Wales the annual death-rate amongst children under one year of age, from all causes, is 18 per cent. We find, however, in manufacturing towns the following startling contrasts as examples. In Liverpool, the infant death-rate per cent. is 30·5; in Leicester, 26·7; in Preston, 26·1; in Leeds, 25·6; in Manchester, 25·1; in Bradford, 23·7. In 155 districts where infantile death-rates are great and abnormally in excess, we notice that manufactures are carried on, in which women are greatly employed. What are the causes of this Herodian slaughter, which one might well wish to be of the merciful speediness of that ordered by the Roman Governor? These children not only die, but their death is usually the last stage of an agonised life, starvation being the chief cause of the mortality. There can be no doubt that the vast majority of these untimely deaths are due to the fact that nursing mothers, who, both for their own and their babes' sakes, should be kept at home, resume their employments much too soon after child-birth. Their children, whilst as yet sucklings, are left in the hands of "care-takers," to whose houses they are carried early in the morning, and of course exposed to cold on the road. It is a trying task for a stranger to have patience with most infants, and this rare virtue can scarcely be expected from an underpaid hireling. The children thus put out to nurse for the day are fed on "bread pobs" or boiled bread, artificial foods of various kinds, and a minimum of milk, if any at all. Indigestion soon sets in, and the "care-taker" is irritated by the wailing and whimpering it produces. Recourse is then had to the "soothing cordial," "which makes a desolation and calls it peace." Numbers of the babies thus dosed by the "care-takers" never awake from this narcotic slumber, and in such cases the doctor, if he be "very particular," may refuse a certificate of death. What follows? To save expense and possibly time, the coroner makes but a hasty investigation, and may even depute the police to institute a few inquiries into the respectability of the dead child's parents. On being satisfied regarding this point, he probably goes no further, thus leaving the real cause of death undiscovered. The infant's life is most likely insured in one or more burial-clubs for the maximum allowed by the law, namely £6. But an infant's funeral can be managed for about £1 15s.; so that a balance of £4 5s. accrues to the parents as the result of the child's death—a point worthy the attention of statesmen, sanitarians, and social reformers generally. Not less significant is it to note what are the most fatal diseases of the children in industrial centres. They are—convulsions, diarrhœa, and atrophy, ailments, that is to say, which are generally induced by improper feeding; atrophy or wasting being simply due to starvation. Amongst such infants measles, too, are very fatal, as also diseases of the lungs, pointing to the deadly effect of early exposure to cold on ill-fed sucklings. The mother who leaves her offspring thus to perish does not escape unscathed. By resuming work too soon after her baby is born she often suffers from grave disorders which it is here unnecessary to specify minutely. One may, however, go the length of saying that a

tendency to debility and faintness is engendered, which, for the moment, may be relieved by the use of alcoholic stimulants, and thus the first step to habitual indulgence is often taken.

What remedies can be found for checking these evils? Amongst the first and most obvious there may be mentioned moral suasion and good advice given to the poor by those to whom they naturally look up. In this connection we may say that it is to be regretted that one does not find more interest shown by the wives and daughters of manufacturers in the well-being of female employées. Many of these ladies are endowed with restless energy, and generous, if vaguely directed, enthusiasm for social reform, which might easily find fit scope for work in such a field as the one we now indicate. A good example has been set them by another class in the community. In rural districts the nobleman's or squire's family pay no small attention to the labouring peasantry, and they create amongst them much kindly feeling, and many firm bonds of attachment by such missions of mercy. Another remedy is the establishment of public nurseries under proper inspection and superintendence. At Stepney, London, E., a *crèche* has been established by Mrs. Hilton, where nearly 130 infants are received early in the morning, fed, nursed, and amused till the mothers return to take them home at night. These families are spared the necessity of receiving parish relief, for the mothers can, without anxiety, leave them while working for their support. The elder children, too, are set at liberty to attend school. A payment of twopence a day is made; and the results have proved what incalculable benefits flow from Mrs. Hilton's model nursery. Other towns, such as Plymouth, are following this good example, but no better institution of the kind exists than that founded by Mrs. Hilton, as a visit to it will at once show. The *crèche* system, which originated in Belgium, presents a feasible solution of the difficulty with which working women have to contend in rearing infants, and it would be well if it were carried out in all manufacturing towns.

As a more certain preventive of infant mortality in the industrial classes, I should suggest that the Legislature might prohibit women in factory districts from resuming work till two months after childbirth. They would then, physically speaking, be better fitted for toil, and their babies would, from eight weeks' nursing at the outset, have a fairer start in life than most of them get now. Next, it should not be allowed that infantile lives may be insured up to £6. This privilege, as it now exists under legal sanction, simply means, in certain painful cases, putting a premium on the production of death. A maximum of £2 would suffice to cover all reasonable funeral expenses, and leave nothing over "to compensate for the bother." Parents would then either not insure the lives of their children at all, or they would be more careful to prevent their dying; at any rate, they would have no pecuniary interest in their burial. Further, the sale of narcotics under cover of patent stamps should be discouraged. If protection be afforded to patent medicines, the exact composition of the nostrums should be stated on the label, so that those using them need have no doubt as to the nature of the drug they are in the habit of buying. Finally, a more rigid inquiry into the causes of all uncertified infantile deaths should be made, and medical as well as police evidence exhaustively taken in every case. Should these suggestions ever be carried out, a marked improvement in the health of our industrial operatives will result. But a caution to future statisticians must be noted. While strong children, well tended, will develop into robust adults, weak infants, who would perish under existing customs, will probably, by wise health-protecting legislation, be spared to a somewhat feeble maturity. Hence we may one day hear the cry of degeneracy of race go forth, when, in fact, abounding instances of defective vitality will be due to the triumphs of sanitary precautions in past years. Investigators of the present day should recollect that the survival of the unfit (even now to some extent) goes on side by side with the predominance of the fittest.

Let us now turn our attention to "half-timers," who have successfully "run the gauntlet" of six or seven years of perils on every side. To what extent do they depart from the average standard of health? There can be no doubt that the young of the human species should, as far as possible, be emancipated from continuous labour, which stunts their growth of body and mind, and ends in the development of an adult feeble in form, and reproducing a rickety progeny. On the other hand, it is the earnest contention of many employers of children—as, for instance, in the silk trade—that they must begin young, in order to acquire the art of delicate manipulation while their fingers are yet lissome. But the Factory Acts are on this point inexorable, and their severity has been justified by results. No child under nine years of age can now be employed in a cotton or woollen manufactory, and a child between nine and thirteen years of age is only allowed to work certain hours a week, the rest of its time being spent in a good

school and in play. The employers bitterly opposed this legislation, and predicted the consequent downfall of our industries. But what says Professor Fawcett, who is notoriously no friend to protective parental legislation? He remarks that "their fears have been signally falsified, for the Factory Acts have effected incalculable advantages. The physical deterioration of the operatives has been arrested. The daily training of the mind helps the development of the body, and it has been conclusively proved that the children who are at school half the day, and are at work the remaining half, acquire vigour, energy, and intelligence; the efficiency of their labour is thus so much increased, that they really do more work in a day than used to be done by those children who were employed *whole time*, and whose strength and activity were exhausted by such excessive toil." If we investigate by a comparative method the nature of the physique of factory children, we find that their alleged degeneration, about which a good deal of excitement has been got up, is not borne out by facts. It is not denied that sickness and deformity exist amongst them; but then they do not exist to a much greater extent than in an equal number of children in other classes. A report to the Local Government Board on the hours and ages of employment in textile factories for 1875, throws the utmost doubt on the reckless assertions of those who, from a narrow range of observation, conclude that the young in the factory districts are rapidly degenerating in physique. In this report, we find given the weights and ages of factory children generally in 1835 and 1873; and, for the sake of comparison, those of (1) agricultural children in Yorkshire, and (2) of London charity-school children. Here are some of the figures:—

Age last Birthday	Factory Report 1835. Weight in Pounds.	Factory Report 1873. Weight in Pounds.	London Charity School, 1873. Weight in Pounds.	Agricultural Children, 1873. Weight in Pounds.
9	51·76	58·72	51·63	60·02
10	57·0	62·74	54·53	65·29
11	61·80	67·92	58·32	71·01
12	65·97	71·06	62·8	75·0

Many thousands of children were weighed and measured in Bolton, Bury, Rochdale, and other towns, in order to supply data for the statistics now cited. As the general result of this inquiry, it was found that the "half-timers" of to-day came up to a much higher standard of physical development than the London charity-school children, who are well housed, well fed, drilled and exercised. This may not say much for the latter; but the figures quoted prove that, instead of manifesting a tendency to degeneration, a factory child aged nine in 1873 weighs more than one aged ten did in 1835, and so on in proportion. Neither do these factory children appear in the matter of physique to be much behind the agricultural children reared in the wholesome atmosphere of the country. "Half-timers," as a matter of fact, may therefore be described as fairly well developed. Of course, they are not without defects. They show, it is admitted, a tendency to suffer from "flat foot" and relaxed joints, with "knock" knees. Their limbs, however, are thick and fleshy. They have hands and feet that are remarkable for their size and strength. Their bodies, it may be said, seem too old for their heads and their ages; but in point of intelligence and acuteness, they are proverbially in advance of all other children born in the lower ranks of life. In agricultural children, on the other hand, the feet are not so frequently "flat," but the legs tend to be "bowed." This latter deformity I think may be due to the fact that the children are tempted to walk sooner than they are in factory districts, and thus their soft and partially ossified bones curve under the superimposed bodily weight. In factory children, the joints are relaxed probably because, in a city, children have not the opportunity of running about so early as in the country. Their bones have therefore time to consolidate, leaving the joints the weaker parts. Another physical peculiarity of factory children is, that they suffer from extremely bad teeth, and from a scorbutic state of the gums, due in all probability to improper feeding when under the hands of the "care-takers." As compared with rural children, they are apt to be dirty, and they are much more frequently infested with vermin. Apart from all this, however, no special congenital diseases can be noted amongst "half-timers." Sometimes slight deformities occur where a particular attitude has to be maintained at a machine, but even this is uncommon. It must be borne in mind that no attempt is here made to prove that "half-timers" are free from disease. They suffer from epidemics as much as—perhaps a little more than—other children; but in discussing this question, the unhealthy state of their homes must be taken into account. Bearing this in mind, the result of a dispassionate investigation compels us to admit that there is nothing about them in the shape of peculiar physical degeneracy or deformity to forbid their employment under the restrictions now enforced by Acts of Parliament and factory inspectors.

SHIP BUILDING.—III.

BRITISH SHIPPING: ITS GROWTH AND PRESENT POSITION.

SHIP BUILDING is one of the most important of the Great Industries of Britain. Other industries excel it in the magnitude of their operations, the number of their workers, and the capital invested in them; but ship building yields to none in its direct influence upon the well-being and integrity of the empire. The maintenance of our national position depends upon the maintenance of our supremacy on the high seas: and that supremacy cannot be maintained apart from the continuous production of new types of ships. Naval architecture is essentially progressive, although its rate of advance is very variable. Types of ships which are most successful in one generation may become antiquated or obsolete in the next; and that nation which is most advanced on the pathway of improvement in ship construction, will almost certainly hold the lead in the commerce of the world. In the Middle Ages this was true of the Genoese and Venetians; later on, the Portuguese and Spaniards were leaders in ship building as well as in maritime enterprise and discovery; then the Dutch created the most powerful fleets in Europe; and now Britain stands pre-eminent amongst nations, possessing a war fleet of unrivalled power, a mercantile marine of surpassing magnitude and efficiency, and resources in ship building well proportioned to her naval forces.

English Ship of the Fifteenth Century.

A thousand years ago, when Alfred the Great had to meet the constant incursions of the Danes, he adopted a policy which is as true now as it was then. Creating a powerful fleet, he aimed at preventing invasion, rather than at the maintenance of an army which could only face the enemy after he had obtained foot-hold on our shores. But while our policy for the home defence of the British Isles is unchanged, the necessity for a powerful navy is infinitely greater now than it was in the time of Alfred. The empire is no longer self-contained and self-supporting: the British Isles are but the heart

of a mighty dominion, of which the several parts lie widespread over all quarters of the globe. Our food supplies are largely drawn from foreign sources; our manufactures and commerce have attained fabulous dimensions, and any serious interruption to them threatens national disaster. British merchant ships float on every sea, laden with the wealth of the world. Rapid and regular communication with our remotest colonies and dependencies has now become not merely a matter of course, but practically a matter of necessity. Our friends in Canada are brought within eight days of home; the passage to Australia is made in six weeks instead of six months. All this commerce requires protection; the outlying parts of the empire need defence; the lines of communication between the mother-country and her colonies must be kept open. In short, what has been gained in territory, in commerce, in shipping, and in wealth, renders it all the more necessary that Britain should maintain the supremacy in maritime power which has been so hardly won. Nor need the loss of this predominance be feared so long as the culture of the science and art of ship building flourishes; for the skill and courage of the British sailor are as marked now as they were in the days of yore, when these qualities often had to counterbalance the disadvantages of meeting a foe whose ships were swifter, larger, and better built than his own.

The period of the great French war was that during which British merchant shipping reached that proud position of superiority over other mercantile fleets which it has ever since maintained. This may appear a singular fact at the first glance, but the explanation is very simple. British war fleets then swept the seas: none but British merchant ships, their allies, or neutrals had a chance of safety. Moreover, the Continental Powers of Europe were engaged in a struggle which taxed their energies to the utmost, and could not attempt the development of their merchant shipping. Hence it happened that while British merchantmen increased in numbers, other European merchant fleets dwindled or stood still. The only sharer in our prosperity was the mercantile marine of the United States; and when the war ended the carrying trade of the world was in the hands of Britain and her revolted provinces, the lion's share falling to the mother-country. When the war began, in 1793, our mercantile marine included 16,000 ships, having a total tonnage of about 1,500,000 tons; when the war ended, there were 21,000 ships, having a total tonnage of 2,200,000 tons, which was a greater tonnage than the aggregate of all the merchant fleets of Europe. Such a condition of things could not continue after the restoration of peace; and before long fears were expressed that the prosperity of the British merchant navy had passed away. British ships were less in request than in the war time; other European Powers resumed the construction and employment of their own merchantmen; and, what was of no less importance, American builders proved dangerous rivals, producing ships of greater excellence than were then built in this country. Nearly all maritime countries were also better supplied than Great Britain with timbers suitable for ship building, and this fact added to the difficulties of British builders. The final outcome of these adverse circumstances was, however, very favourable to this country. Under the stress of competition, the designs of merchant ships were improved, injurious tonnage laws were abolished, the value of scientific methods of construction was more fully recognised; and, finally, the introduction of iron hulls and steam propulsion, in both of which this country took the lead, relieved British builders of serious drawbacks to successful rivalry with foreigners. We can no longer hope to be the possessors of the carrying trade of the world; but we have so large a share of that trade that we may well be content. Instead of seeking for models in the vessels of other nations, as was commonly done in the last century, British ships are now models for the world. The enterprise of British merchants and ship builders has re-created not merely our own mercantile marine, but that of every other important maritime power. Formerly our chief claim to pre-eminence was in the number of our ships, not in their qualities; now we can fairly assert superiority in both numbers and qualities, and the claim is frankly admitted by other nations.

Before sketching the history of British shipping, it will be interesting to state briefly its present position. At the end of 1875 the United Kingdom owned more than six millions of tons of merchant shipping; and more than a million and a half tons were owned by the British possessions. Altogether, the tonnage of merchant ships belonging to the British Empire was about $7\frac{3}{4}$ millions; the number of ships exceeded 37,000, and the crews exceeded 342,000 men and boys. Within a period of less than sixty years the tonnage had been trebled, and the number of ships nearly doubled, after allowing for the wear and tear of service. The methods of constructing and propelling ships had been revolutionised; the commerce and intercom-

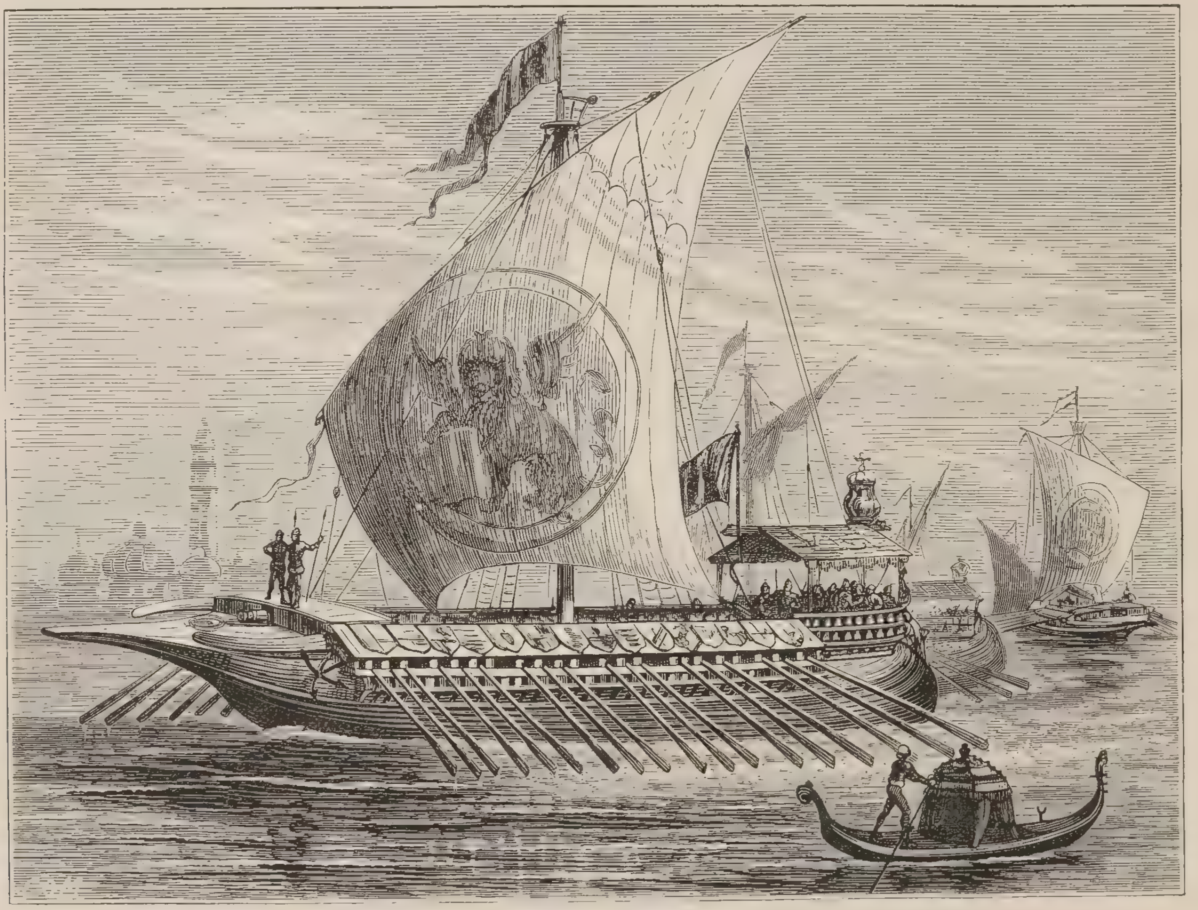
munication of the world had been vastly increased. The British mercantile marine exceeds in tonnage the united merchant fleets of France, Germany, Italy, Norway, and Austria. The Dominion of Canada possesses a fleet which will compare favourably with that of the great maritime Powers of Europe. Australia and New Zealand are both creating a mercantile marine which already considerably exceeds that of Portugal or Denmark, and does not fall much below that of Spain. The only marine which at all bears comparison with our own is that of the United States; but even that fleet, with a total tonnage of about $4\frac{1}{2}$ millions, has only two-thirds the tonnage of our own. The great natural resources of the States, the skill of Americans as ship builders, and their vast coasting and internal navigation, all tell in their favour, and point to a possible future when they may either equal or surpass Great Britain as ship owners. Twenty years ago it appeared as if the time had come when we might have to yield the place of honour so far as the mercantile marine was concerned. Ship building was then advancing in the United States at a much greater rate than in Great Britain. In 1821 the total tonnage of British shipping slightly exceeded $2\frac{1}{2}$ millions, and was about double that of shipping owned in the United States. In 1841 the British tonnage had reached $3\frac{1}{2}$ millions, while that of the States somewhat exceeded 2 millions. In 1861 the British tonnage stood at 5,900,000 tons, and that of the States at 5,500,000 tons, or nearly equal to that of the mother-country. Since then very serious checks have been put upon American shipping by the Civil War, the rapid advance of iron ship building, the progress of steam navigation, and other causes. As a consequence, in 1871 the total American tonnage had decreased to 4,200,000—little more than the tonnage twenty years before; whereas British shipping had gradually reached a tonnage exceeding 7,000,000. American ship building revived, however, about five years ago, and during the period 1872-75 about 440,000 tons was the increment to the total tonnage. But even this great addition has been exceeded for British shipping, of which the tonnage has been increased in the same period by about 550,000 tons. At present, therefore, there is no reason to apprehend a loss of our proud position as the first ship-building and ship-owning nation in the world.

As an item in the national estate, our mercantile marine has an enormous value, probably approaching one hundred millions sterling. But the value of the commerce of which our merchant ships are carriers to and from our shores, far transcends this enormous sum. For many years the annual value of imports and exports has exceeded 650 millions; and of the 45 million tons of shipping which have entered and cleared at British ports during each of the last three or four years, two-thirds have been British ships. In other words, two-thirds of our home trade is carried on by our own ships. Some patriotic persons express regret that a single foreign ship should have a share in British trade; while, at the same time, they desire that British ships should obtain a still larger share of the foreign carrying trade. This is scarcely reasonable; and our great advantage over all other nations will appear from the following facts. According to the official returns, about seventy per cent. of the foreign trade of the United States is carried on by foreign ships, and only thirty per cent. in American vessels; the proportion of home to foreign ships being the reverse of that which holds in this country. Of the seventy per cent. of foreign ships trading to ports in the States, by far the greater part carry the British flag.

It has become so much a matter of course for Great Britain to stand at the head of the maritime world, that we are apt to forget the long centuries during which she occupied a subordinate place. Keeping in mind the foregoing figures for the present condition of our fleet, it will be a strange contrast to run over the muster-rolls of past days. In 1344, Edward III. ordered a return of the whole maritime force of his kingdom: it was found to consist of about 700 ships, manned by about 14,000 men. Seventy years after, Henry V. gathered all the vessels in England of twenty tons burden and upwards, in order to transport his army of 30,000 men to France. Having reinforced the English ships by vessels hired in Holland and Zealand, he had 1,500 ships at his command, giving an average of twenty men carried by each vessel, exclusive of her own crew. The *Great Eastern* can carry 10,000 troops at one time, or one-third the whole army which Henry conducted into France!

For centuries before this invasion, and for a long time after it, the Mediterranean States, and more particularly Venice and Genoa, had possessed powerful fleets, fitted for commerce and for war. When the fourth crusade took place, the Venetians furnished ships capable of conveying 4,500 knights and 20,000 infantry, with fifty galleys as an escort; and some vessels employed in this service are said to have carried 800

persons. Nor was Genoa an unworthy rival; for in the wars with Venice, towards the end of the thirteenth century, it is said that fleets were equipped numbering from 100 to 300 vessels, the galleys each carrying over 200 fighting men. Nor were the Mahometan States deficient in maritime force. When Richard Cœur-de-Lion was on his way to the Holy Land, it is related that he captured a vessel belonging to the Saracens which carried 1,500 men, and a large quantity of stores. Redcliffe, which he had built. Some doubts attach to the statements respecting Canynge's fleet; but it seems certain that he owned several ships, which were of great size as compared with other English ships of the period, measuring from 400 to 900 tons; and that the total tonnage of his ships did not fall much short of 3,000 tons, manned by 800 seamen. Canynge had few rivals, however; and, as a whole, English shipping suffered greatly from the civil wars, so that on the accession of



Venetian Galley.

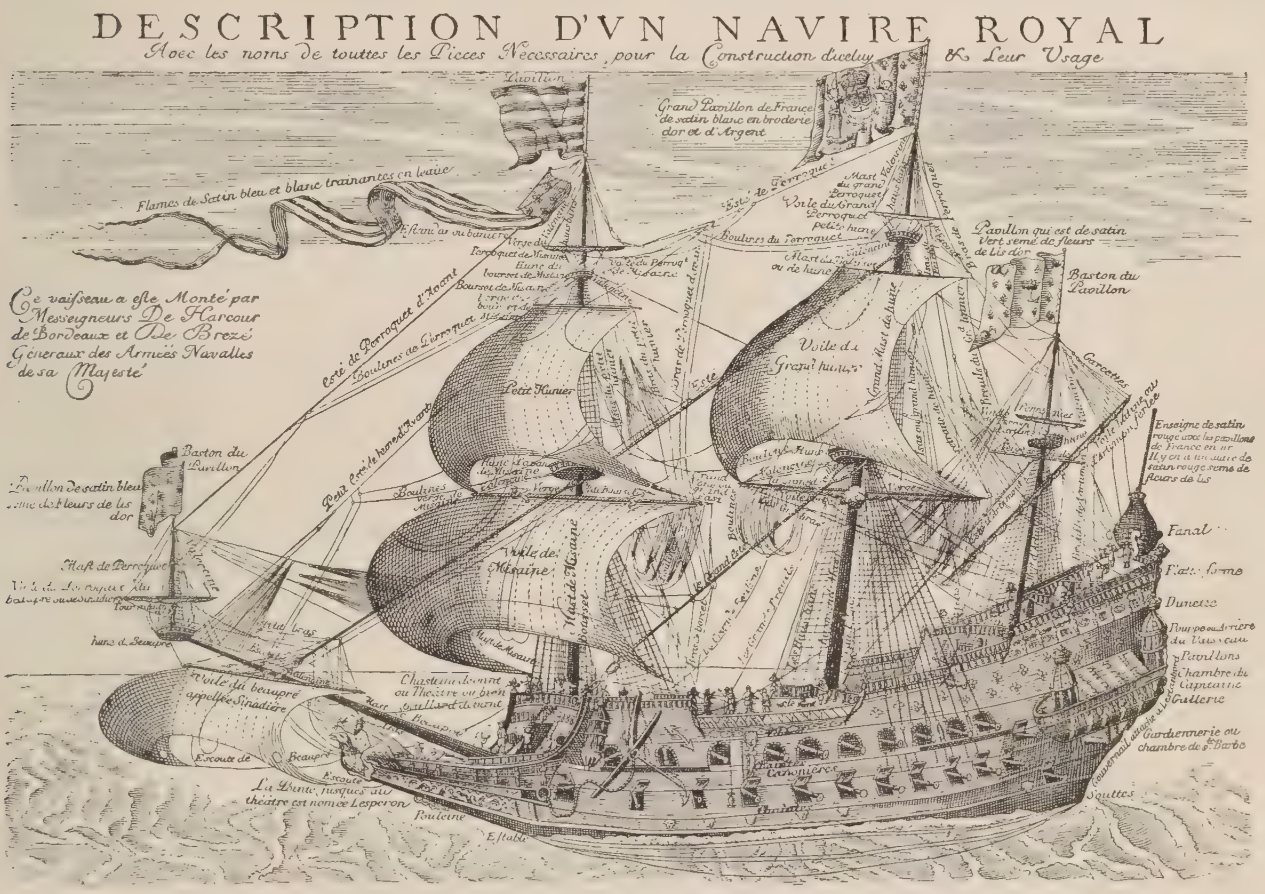
Almost at the same time that Edward III. invaded France, the Turks were preparing to undertake the invasion of Europe; and for that purpose assembled a fleet of 300 ships, with an army of nearly 30,000 men. When Henry V., with infinite trouble, collected 1,500 English and Dutch ships, Venice is said to have owned 3,000 merchant ships, besides ships of war.

There is, however, evidence that amid the trouble and internal strife of England during the fifteenth century, the interests of trade and shipping were not altogether overlooked. One of the most famous merchants of that time was William Canynge, of Bristol, who was buried in the Church of St. Mary

Henry VII. it was in a very depressed state. That monarch did something to revive the shipping interest; and Henry VIII. did still more—becoming, in fact, the founder of the Royal Navy as a force exclusively devoted to war service. In the earlier times, the sharp dividing line now existing between ships for war and ships for commerce was not in existence. When the royal ships were not required by the State in times of peace, they were hired by merchants; and in time of war, the few royal ships were reinforced by numerous merchantmen, upon which the defence of the kingdom virtually depended. Merchant ships were readily adapted to warlike purposes, and were not

unfrequently found more handy and serviceable than the royal ships. The larger number of these auxiliaries were furnished by the Cinque Ports, which were bound to do so by their charters. When a sufficient number of ships could not be obtained from these ports, all other English ships were liable to impressment, and foreign ships were often hired. Every foreign war, consequently, caused a serious interruption to commerce—not merely by the hindrances and dangers resulting from the war, but by the withdrawal of ships from commercial pursuits, and their employment in warlike services. It is easy to see, therefore, why English commerce compared so unfavourably with that of many other States up to the end of the fifteenth century. Repeated invasions of France, civil wars, changes of dynasty, want of settled government, all told against material progress. There was then but little probability that England would ever attain the position of the greatest maritime nation in Europe and the world.

Passing on to the time when every nerve was strained to equip an English force capable of encountering the Spanish Armada, let us note what was the state of our shipping. In 1578, it is said that there were in England only 135 ships exceeding 100 tons burden, and only 656 ships having a burden of from 40 to 100 tons. The fleet which fought and defeated the Spaniards consisted of less than 200 vessels, having an aggregate burden of about 30,000 tons. Only one-sixth of this force were men-of-war: the rest were merchant ships. Some of these were of only thirty tons burden, and one-third of the total number were under 100 tons each—smaller, in fact, than many of the yachts and fishing smacks of the present day. The largest English ships of that period about equalled in tonnage the sloops or small merchantmen now employed: the total tonnage of the English fleet would be represented by five or six mail steamers, four or five ironclads, or by two *Great Easterns!* This was the utmost force that England could muster in her hour of need: such were the small and fragile vessels that met and conquered the grandest fleet that had ever floated in European waters. The Armada consisted of 133 ships only, but their aggregate tonnage was nearly twice that of the more numerous English ships. Seamanship



FRENCH WAR-SHIP OF THE SEVENTEENTH CENTURY. *(Reduced Fac-Simile of a Print of the Period.)*

and courage triumphed even under these conditions, and the bold commanders turned the small size of the English ships to account; closing with the high-sided Spanish ships, the guns of the latter are said to have fired "over the heads of the English, without doing any execution." In dwelling upon this glorious victory, let it ever be remembered that all the conditions which make it remarkable also furnish evidence of the inferior position occupied by British shipping among the fleets of Europe towards the close of the sixteenth century.

Although Queen Elizabeth fully appreciated the great importance attaching to the possession of shipping, and added largely to the royal navy, her reign is chiefly noticeable for the skill and courage of English seamen, comparatively small progress being made in the numbers, size, or efficiency of English ships. The exploits of Drake, Hawkins, Frobisher, Davis, Raleigh, and many others are wonderfully interesting; but the full measure of their daring is only to be ascertained when the small size and scanty equipment of their ships are considered. To the enterprise of these "private adventurers" were due the destruction of the huge monopolies which Spain and Portugal endeavoured to set up, the breaking down of barriers by which these nations sought to inclose the riches of the New World, and the establishment of a world-wide reputation for the English as a maritime nation. They were the pioneers, who did but little trading themselves, but made it possible for English commerce to spread far and wide.

Before English shipping reached the first rank, many a hard fight had to be fought with more formidable enemies than the Spaniard. The Dutch and English had made common cause against Spain, but their interests soon diverged, and a contest ensued during the latter half of the seventeenth century which for vigour and fierceness is probably unsurpassed. In this great series of naval actions, victory sometimes inclined to the one side, sometimes to the other. So late as 1667, the Dutch sailed up the Medway, did great damage at Chatham, and threatened London. But while the English war fleet, strengthened by Charles I. and his father, and greatly improved during the time of the Commonwealth, could rival that of Holland, it did not prove the victor until aided by the French fleet, which had been created by the vigorous administration of Louis XIV. When the Dutch finally yielded to the force of arms, they still retained a formidable war fleet and a mercantile marine of unapproachable extent and excellence. Early in the seventeenth century, Sir Walter Raleigh credited Holland with the possession of as many merchant ships as were owned by England and ten other European States. One thousand new ships are said to have been built annually. Evelyn asserted that about the middle of that century, Holland possessed 20,000 sea-going vessels of all classes, some of them doubtless being of small size; and Sir Henry Petty said that they owned nearly one-half the total tonnage of European shipping—England owning about one-fourth.

The defeat of the Dutch war fleets, the establishment of the great trading companies in England, of which the East India Company was the chief, the enactment of stringent navigation laws, which were designed to exclude foreign shipping from English trade, and the wonderful progress in colonisation which had been made during the preceding century, all contributed to the advancement of the English mercantile marine relatively to that of the Dutch. In fact, further rivalry with them was of a peaceful character, and the accession of William III. led to the junction of the forces of the two in opposition to the French. By that time the French navy had reached dimensions which enabled it to compete with any war fleet. In 1661, the French force is said to have consisted of four or five small vessels, England and Holland then equipping fleets of more than a hundred men-of-war. Twenty years later, the French possessed nearly 300 war ships, manned by nearly 40,000 men; and when the war with England began, the French for a time had a more powerful fleet afloat than was brought against them by the English and Dutch. The contest thus begun lasted for twenty-five years, and in the end France was defeated, although it is unquestionable that she possessed finer ships than England, and was beaten only by the superior skill and courage of her opponents. All through the eighteenth century, war followed war in rapid succession, France and Spain usually combining against England, which held its own even against these odds. The losses incurred in these continued struggles were very great, the hindrances to progress were serious; but still our mercantile marine flourished. In the year 1701, the total tonnage of English merchant ships was estimated to be less than 300,000 tons; the total number of ships being about 3,300. Ninety years later, there were over 16,000 merchant ships, of which the total tonnage exceeded 1,500,000 tons. From that time onward, Great Britain has had no successful rival to her naval supremacy.

HEMP, FLAX, AND JUTE.—III.

INSIDE A FLAX MILL—SPINNING AND WEAVING.

By David Bremner, Author of "The Industries of Scotland."

BEFORE proceeding to deal with flax and its cultivation, or touching the curious history of the linen manufacture, it may be well to excite the interest of the reader in our subject by describing in a general way what may be seen inside a flax mill. In the construction of flax mills, as well as of the machinery employed, a great improvement has taken place during the last twenty years. Though there are still in existence many of the buildings erected before the idea that the health of the work-people was a thing to be considered, had dawned upon the minds of mill-owners, these structures have for the most part been altered in order to adapt them to modern requirements, and now the lot of the operatives is far different from what it used to be. In Yorkshire, Forfarshire, and the Belfast district, flax mills are now to be seen which may be described as palaces in comparison with the low-roofed, small-windowed buildings in which flax spinning and weaving were carried on at the beginning of the century. Externally there is little in the appearance of a flax mill to distinguish it from a cotton or woollen factory—except, perhaps, the colour and abundance of the dust emerging from and deposited upon the windows of the preparing departments. The machines employed in these departments have been specially devised for working flax, but those used in spinning and weaving are simply modifications of those which were invented for dealing with cotton. Some flax mills are devoted exclusively to the production of sail-cloth, and other heavy fabrics; some turn out table-linen only; while in others attention is confined to the making of cambrics. Generally, however, the productions of a mill embrace a wide range of goods, and to the making of cloth the spinning of sewing-threads is occasionally added.

There are many establishments that might have been selected as models for description; but in this paper it is preferred not to identify the factory to which the reader's attention is invited. Let us suppose that we have arrived at the mill, and that the entrance of carts loaded with bags of flax at one gateway, and the exit of carts loaded with compact bales of manufactured goods at another gateway, have been duly noted. An intelligent guide having been detailed to escort us, we proceed to inspect the works. The first department that claims attention is, of course, the store in which the raw material is received and kept ready for use. The flax arrives at the mill in bags, direct from the scutching mills in the locality where it was grown; the supplies being drawn chiefly from Ireland, Russia, Germany, Belgium, and Holland. On being removed from the bags, the flax, which is made up in bundles of convenient size for handling, is carefully examined, to see that it is of the specified quality, and is then built up in racks ready for removal to the hackling room. The latter is a department in which the visitor is not likely to make a prolonged stay. Though the apartment is large and lofty, the process to which the flax is here subjected creates so much dust, that the air is literally thick with it—so much so, that the figures of the workers in the remote parts of the room are at times but indistinctly seen. By fans and ventilators, the more deleterious particles of dust are drawn off, but still enough is left to render the occupation of the persons employed in this department anything but pleasant, and it is certainly unhealthy. The heavy odour which clings to the flax after the "retting" process—that is, the steeping which the flax-straw has to undergo, in order to separate the fibre from the woody core—adds to the disagreeableness attending the hackling. For some purposes flax is still hackled by hand, much in the same manner as hemp; but by far the greater part of the fibre is hackled by machines of various construction, which perform the work with great celerity and completeness. The object sought to be accomplished by hackling is thoroughly to remove the tow and split up the finer portion of the fibre into minute hairs. The more carefully the operation is performed, the finer and proportionately stronger will be the yarn produced. In hand-hackling, the workman takes a bundle of flax, and draws it over steel spikes arranged on a bench. The first set of spikes are very strong and wide apart; and, after the flax has received a first combing on these, it is drawn over a second set of spikes of more slender form, and arranged more closely; from these it is passed to a still finer set, and so on until the separation of the fibre has been carried out to the desired degree, the quality of cloth to be made determining the treatment of the flax at this stage. Of the hackling machines,

Great Hall in Messrs. Marshall's Flax Mill, Leeds.

the most efficient, and at the same time most ingenious, is that known as the self-acting sheet machine. The main part of this machine consists of a stout endless apron or belt, made of leather, and studded with spikes, similar to those in the flat hackles used for hand hackling. The apron is mounted on rollers, by which it is set in motion, and is so arranged as to present at the front part of the machine a flat surface, and it is on this that the hackling is actually accomplished. The spikes on the apron are arranged in half a dozen parallel bands, the spikes in the successive bands being of an increasing degree of fineness, so that as the apron moves round on its rollers it presents continuously on the flat section referred to a complete set of hackles. Let it be noted here that the difference between machine and hand hackling is this—that, whereas in the latter the flax is drawn over the spikes, in the former the spikes are drawn through the flax, which has to be firmly held in a suitable position. Before the flax is presented to the hackling machine, it is "ended"—that is, it is taken in small bundles, and the ends alternately submitted to the action of a strong little machine, which tears off the entangled portion of the extremities, and draws the fibres parallel. The operatives who attend to this part of the work give to each bundle of the flax a slight twist in the middle, which keeps it distinct from its neighbours, and facilitates subsequent operations. In this form, the flax is taken to the hackling machine. Here the bundles are successively fixed near one end in a pair of wooden clamps, and, thus held, are fed into the machine. Immediately over the point at which the apron assumes a flat surface, a rail passes from side to side of the machine, and on this rail the clamps, with their pendent tufts of flax, are placed. Let us suppose that the machine is just being started, and watch its operation. The flax is fed in from the right-hand side of the machine; and, as it passes along the rail, is brought into contact with the different sets of hackles in succession, pausing over each for a sufficient time to allow the spikes to accomplish their work thoroughly, first on one side of the bundle and then on the other; for by an automatic movement the clamps are turned over each of the bands of hackles. As one lot of flax passes from the coarser to the finer hackles, fresh lots are fed in, so that soon all the hackles are at work simultaneously. The finished bundles drop off the rail at the left-hand side of the machine, where they are received by an attendant, who unscrews the clamps, and places them on the dressed end of each bundle, ready to go through the machine again, so that the end held in the clamp during the first passage over the hackles may be operated upon. When the flax receives the final hackling, it presents a beautiful silky appearance.

Leaving the dust and din of the hackling room, we ascend to the floor where the drawing machines are situated, and there witness the first stages of the spinning process. Here is some flax brought from the hackling room, and we must note what is done with it. Taking up handful after handful of the shiny fibre, a smart girl arranges it on the feed-board of a machine so that the ends of the successive bundles overlap each other. Thus placed, the flax is drawn between rollers, and disappears from that point of view. If we step round to the front of the machine we shall see what has become of it. There it is moving along in a continuous stream, so to speak; but its path is a very thorny one, as it lies over a travelling belt of fine spikes, the points of which show through it during its whole course. On close observation it will be seen that the hackles travel at a quicker pace than the flax, and thus remove all tangled portions, and help to bring the fibres into the parallel order essential to spinning. From the hackles the flax passes to a set of drawing rollers, by which the soft ribbon or sliver which it now forms is elongated to a certain extent. As it emerges from the rollers the sliver is received in a tall tin can, in which it is removed to another drawing machine, which is almost identical in construction with that whose working we have just been noting. It is, however, fed in a different way. Eight of the slivers formed by the first machine are taken together, and as they pass over the hackles and through the rollers are drawn out until they are reduced in thickness to one-eighth of the aggregate bulk. This process is repeated again and again until a fine even sliver is obtained. As yet, it will be observed, the fibre has received no twist, and as it will not bear handling it is moved about in the cans into which it falls from the machines. The next process is the conversion of the sliver into a roving, or slightly-twisted cord. For the accomplishment of this the machine on which the last drawing takes place is furnished with bobbins and flyers. These receive the sliver from the last pair of drawing rollers, and by a simultaneous process impart to it the desired degree of twist, and wind it upon the bobbins. The latter, when filled, are removed to the spinning frame, where they are placed on pins arranged in line upon the top of the

machine. Each roving is then led between drawing rollers, and attached to a bobbin and flyer. As it passes between the rollers it is elongated to the required extent, and the spinning operation is completed by the bobbin and flyer. Some of the flax is spun by the wet process, which better adapts it to certain purposes. In wet-spinning the roving in passing over the spinning frame is made to dip into a receptacle filled with water heated by steam. The hot water softens and separates the fibres, and admits of their being drawn out into a finer thread than if spun dry, while at the same time it causes the loose fibres to combine better with the body of the yarn. Wet-spinning used to be considered prejudicial to the health of the operatives; but as now conducted there is little to complain of. When the bobbins have been filled they are passed to the reelers, who make the yarn up into convenient forms for bleaching or the loom.

We must now leave the region filled by the steady humming of the spinning machinery, and pass to that where the clash of the looms invites us to fresh scenes of interest. But first we must peep into the room where the warps are arranged and mounted, and the yarn receives a dressing of paste to give it greater solidity in the loom. The yarn having been wound on the warp-beam, the latter is placed at one end of a machine having at its central part a trough, or cistern, filled with paste, and through this the yarn is drawn and allowed to take up sufficient of the dressing to make it, when dry, firm and smooth. It is dried by being passed over heated rollers. Each separate thread has then to be passed through the heddles and reed of the loom, and after some adjustment all is ready for weaving. The looms on which plain linen is woven are similar to those used in cotton factories; while for figured cloths and damask, the ingenious and complicated Jacquard machine is employed. Of the different kinds of loom, several hundreds are in operation here side by side, and the noise they make is deafening, and, to one unaccustomed to it, positively distracting. The shuttles, impelled by untiring arms of iron, fly with lightning swiftness, and thread by thread the fabrics are formed at a pace that the deftest hand weaver could never hope to attain. Of all the machines, the Jacquard loom is the one that excites most wonder in the eyes of the casual visitor. The movements of the thousands of perforated cards which perform the function of working out the pattern from a lofty perch overhead, and the maze of gliding and dancing cords which these control, seem so complicated and mysterious, as to fill one with admiration of the genius that devised the whole, and make one regard with most respectful feelings the loom-tender who has made it his business to master the intricate mechanism. Here is one of these machines, on which a table-cloth of elaborate device is being fashioned. Watch its operation for a moment. Overhead the cards move forward one at a time; then there is a pause, a movement among the cords, a flight of the shuttle, and a bang of the reed. So one thread of weft is put in. Look, now, at the web in the loom. The warp is a snowy plain of parallel threads extending forward from the dense bank of "harness," as the cords which lift the warp threads in response to the action of the cards are called. At each movement of the loom the warp is opened up for the passage of the shuttle, and it is the manner of this opening up that determines the pattern which is being developed at each flight of the shuttle. The threads are raised now singly, now in groups, and in seemingly aimless confusion; yet the fact is, that the position of every thread in the piece is being put in upon a most carefully prepared plan. For each thread of weft there is a perforated card in the loom which determines the part that particular thread will play in the elaboration of the design which the cloth is intended to bear. Here we see a picture in white produced upon a white ground; when the loom is employed on coloured cloths its operations may be more clearly followed. However used, it is a marvel of mechanism, and the memory of the inventor well merits all the honours that have been bestowed upon it.

After leaving the loom the webs are, according to circumstances, treated in various ways: some being bleached and glazed, while others are merely calendered. The calendering department is always an important one in a linen factory, as the beauty of the cloth depends largely on its treatment therein. There are lapping machines for folding the cloth, and hydraulic presses for reducing the bulk of bales; besides other appliances too numerous to note on a cursory visit, but all of which will be fully described in subsequent papers.

The engraving which accompanies this paper represents a room in the extensive and well-known flax mill of Messrs. Marshall and Co., Leeds. This apartment is remarkable for its size, the floor measuring nearly two acres in extent, being 132 yards long and 72 yards wide, and it is calculated that it would furnish standing accommodation for no fewer than 80,000 persons. The roof, which is

twenty feet above the floor, consists of sixty-six brick arches supported on iron pillars, and is furnished with an equal number of dome lights measuring forty-eight feet in circumference. As the domes rise about a dozen feet above the roof, they answer the purpose of ventilators as well as supplying an abundance of light. All the operations of spinning and weaving are conducted in this room, by the aid of apparently innumerable machines. The part which the artist has chosen for his sketch, is that in which the drawing machines are situated. In the centre may be seen the machines on which the bunches of flax brought from the hackling room are formed into a sliver, and on the left hand are machines which operate on eight of the slivers thus formed, and draw them out into a single one, which process having been repeated again and again, gives to the fibres the parallel arrangement essential to their formation into yarn.

SHIP BUILDING.—IV.

CENTRES OF SHIP BUILDING.

SIX rivers of Great Britain may fairly be styled the great centres of ship building. For many years past the Clyde, the Tyne, the Wear, the Tees, the Mersey, and the Thames, have produced more than three-fourths of the total tonnage of ships built in the United Kingdom. There are, of course, many other ports where a large amount of tonnage is annually built, and which may hereafter attain even greater importance than they at present possess. Hull, for example, was famous for its ship building centuries ago, and still holds a high place. Barrow-in-Furness has made wonderfully rapid progress, and is still advancing. Belfast occupies a good position, not merely because of its large annual "out-put," but because some of the finest merchant steamers afloat have been built there. Nor are Aberdeen and Dundee without claims to recognition on account of their ship building trade. But after reviewing the claims of all these and many other ports, it will be seen that no injustice is done in placing in the first rank the six rivers named above. Ship-yards are still scattered along the coast, and doing useful work; but the greatest developments of iron and steam ship building have not been made in these establishments, and their practice is antiquated or imperfect as compared with that of the great ports. Half a century ago it would have been difficult to point to any other important industry of which the practice was more widely distributed than that of ship building; but the tendency to localise and concentrate the trade has since been most marked. On the Clyde this tendency has been most fully illustrated, and we will begin our survey of the centres of ship building on that river.

The Clyde ports, from Glasgow down to Greenock, have for years past produced quite one-third of the total tonnage built in the United Kingdom. A trip down the river in one of the swift passenger steamers for which the district is famous, cannot fail to impress a visitor with the magnitude of the operations carried on in the numerous ship-yards which line the banks. Starting from the Broomielaw, he sees lying afloat many first-class ocean steamers, and will wonder when he is told that within the memory of many men still living it was possible to wade across the river, at low tide, near where these noble vessels now lie. The energy and enterprise which the corporation of Glasgow displayed in undertaking the works which have wrought this wondrous change, and made their city a sea-port, have been richly rewarded. It has resulted not merely in a vast increase of trade, but in an unrivalled development of the ship-building industry. The engineers and ship builders of the Clyde were amongst the first to appreciate the advantages of steam propulsion, and of iron hulls; but their conceptions could never have been fully realised in the construction of large ships, had not the river been rendered navigable. Even now it is a matter for surprise to the visitor that ships of the great length and weight commonly built at Glasgow can with safety be launched into a comparatively narrow river. Care and skill triumph, however, under even these adverse circumstances, and it is no exaggeration to say that the Clyde stands pre-eminent in the construction of ships of all classes and sizes, competing successfully with other places which possess far greater natural advantages. Some of the finest iron-clad ships of the Royal Navy, and many of the largest trans-Atlantic steamers, have been built at Glasgow. Ships for war and

commerce, paddle and screw steamers, sailing clipper ships, powerful steam dredges, such as have been so successfully used in deepening the Clyde itself, and many other types, can be inspected in all stages of construction. But everywhere iron and steel will be found in use, and a wooden ship will scarcely be seen.

It is difficult to make clear to the general reader the real magnitude of the work done annually by the Clyde ship builders. Take the year 1873, for example, and it appears that no less than 143 ships were launched, having a gross tonnage exceeding 230,000 tons. The value of these new vessels probably approached *six millions sterling;* and at the end of the year there remained on the stocks a total tonnage of more than 190,000 tons. It has been said, and doubtless with truth, that the Clyde alone produces more new ships than all the ports on the Continent of Europe taken together. Even when compared with the aggregate tonnage built in the United States, the out-put of the Clyde yards appears very considerable. In 1873 and 1874 the American yards produced about 800,000 tons of shipping; during the same years the Clyde yards launched about 500,000 tons. In the ten years, 1868–1877, the total tonnage of ships launched on the Clyde considerably exceeded two millions of tons.

The largest ship-building establishment on the Clyde is that of Messrs. John Elder and Co. It covers about sixty acres of land, and contains not merely a large plant for ship building, but also a magnificent engine factory, where the machinery and boilers are constructed for the ships built in the yard. On an average 4,000 men of all trades are employed, and the annual out-put has sometimes exceeded 30,000 tons—about 50 per cent. in excess of the annual increment made to the tonnage of the Royal Navy from all sources, and about equal to the total tonnage of the English fleet which encountered the Spanish Armada. A single private establishment can now produce in a single year shipping of equal tonnage to that mustered under circumstances of extreme peril from all parts of England three centuries ago! But even this statement of the contrast is incomplete; the modern ships would be far superior in size and structure to their predecessors, and nearly all of them would be fitted with powerful engines, capable of propelling the vessels against wind and sea. Messrs. Elder undertake the construction of all classes of ships; and at various times have built ships for the Royal Navy. The reputation of the firm is, however, mainly due to their success in the construction of ocean steam-ships. The late Mr. John Elder was one of the chief advocates of engines on the "compound" principle, which greatly economise fuel, and render it possible for vessels of moderate size to perform the longest ocean voyages under steam.

Limits of space prevent reference to any of the other eminent Clyde ship builders, whose vessels are well known all over the world. Many of these firms devote themselves to the construction of special classes of ships. Some, for example, excel in sailing-ships, a large number having been built recently, notwithstanding the progress of steam navigation, and competing with steamers on distant trades, like that with China or Australia. Other firms pay special attention to shallow-draught ships; many of these vessels are erected on the Clyde, then taken to pieces for transhipment to the localities for which they are built, and finally put together there. Cargo-carrying vessels furnish the staple industry to still other firms; and the nondescript small fry of barges, dredges, tugs, &c., are constructed in yards where larger classes of ships are rarely if ever laid down. On the Clyde the bulk of the work done is in *building* ships; one may travel far along either bank of the river and see but few establishments where repairs are undertaken. There are, however, a few such repairing yards, and one of the most notable of these is that of Messrs. Inglis, where one of the largest hauling-up slips in the world may be seen in operation. Another notable fact is that by far the greater number of the leading firms on the Clyde are engineers as well as ship builders; not a few having been engineers originally, and having added ship building to their business, when the construction of iron ships began to be practised.

The Tyne, unlike the Clyde, has for a very long period been known as "a nursery of shipping," to quote the words of a committee of the House of Commons in 1642. In the reign of Edward III. the coal-fields in this district were first worked, and a large export trade soon sprang up. London and the south of England began to receive "sea-borne" coal, and France became an extensive buyer. Newcastle consequently became a great centre of shipping and ship building; and when Sir Walter Raleigh summarised the naval force of the kingdom, in his "Invention of Shipping," he laid great stress on the value of the "two hundred sail of crumsters or hoyes of Newcastle," which "may be chosen out of four hundred." When wood ships began to give place to iron, the Tyne ship builders did not at once begin the construction of iron ships, although they

SHIP-YARDS AND SHIPPING ON THE CLYDE.

were so well placed for the practice of the new industry; but in 1840 the first steps were taken, and now very few wood ships are built. As the visitor passes down the river from Newcastle to Tynemouth he may see here and there a wood ship in frame, but the skeletons of iron ships will meet his gaze on all sides. On the Tyne the ship-yards are not clustered so closely as they are at Glasgow; and the character of the river-banks, with the numberless factories planted thereon, is so entirely different from that of the Clyde that it is very difficult for an observer to appreciate the scale upon which ship building is carried on. The trade on Tyne-side is not nearly so considerable as that on the Clyde, but it is, nevertheless, very important: the tonnage built annually for many years past has averaged about 50,000 or 60,000 tons. Cargo-carrying steamers of moderate speed are the types most commonly produced, and they do their work exceedingly well. Other classes are, however, by no means neglected, and the Tyne can boast of iron-clad war-ships as well as first-class mail steamers built on its banks. Two specialties of this river are its steam colliers and its tugs. The latter are built in considerable numbers, and employed all round the coast; while the colliers are so well adapted to their special work as to deserve a brief notice.

Prior to 1850, only sailing colliers were employed in the trade with London; but they could not compete successfully with the railways, and iron screw colliers were then introduced by Mr. C. M. Palmer. The pioneer vessel was named the *John Bowes*, and her first voyage was an earnest of what the new type would accomplish. In four hours she received on board 650 tons of coal, her passage to London occupied two days, her cargo was discharged in twenty-four hours, and within five days after leaving she was again in the Tyne, having accomplished an amount of work which would have occupied two average-sized sailing colliers a full month. Since 1850, many changes and improvements have been made in the screw colliers, and whereas in 1859 these vessels brought about 550,000 tons of coal to London, in 1869 they brought 1,700,000 tons. The colliers now in use are larger and swifter than those of twenty years ago; hydraulic and other machinery is largely used for loading and unloading their cargoes, and time is further saved by the use of water ballast. Formerly rubble ballast was used, and when a collier had discharged her cargo a considerable time was occupied in putting ballast on board for the return voyage. On her arrival in the Tyne, this ballast had to be discharged, at the cost of much time and labour, and the huge "ballast heaps" which abound along the river-banks—puzzling the visitor who strives to guess their origin—bear witness to the great savings which have resulted from the use of water ballast. Cellular tanks are formed in the bottoms of the colliers, and as soon as their cargoes are discharged they at once start on the return voyage. On the way down the Thames the ballast tanks are filled with water, and the vessel is in sea-going trim by the time she reaches the Nore. On her arrival at Tynemouth, or even sooner if the weather is favourable, the operation of pumping out the water ballast is commenced, and continued as the vessel makes her way up to the loading stage. Coal-laden railway trucks there await her, her loading at once begins, and by the time this is finished the ballast tanks are free, and the collier is ready to start on another trip.

The Wear and the Tees have much in common with the Tyne, and the practice of ship builders, as well as the types of ships produced, in these three districts are very similar. Of the three, the Wear is the most productive of new ships, and the Tees occupies the lowest place; but even the Tees much exceeds in its out-put the Mersey or the Thames. Taking these north-eastern districts together, it appears that in the period 1871–75 they produced a greater tonnage than the Clyde; and during the year 1877, when the trade on the Clyde suffered severely from strikes, the north-eastern districts not merely gained relatively, but produced a greater tonnage than they had ever attained before. It is, indeed, obvious that so far as regards natural advantages for carrying on the business of iron ship building, these three rivers surpass the Clyde. Flowing through a great coal and iron district, the materials required by the ship builder are ready to hand, and cheaper than elsewhere. The lead which the Clyde has obtained must, therefore, be attributed mainly to greater enterprise on the part of the Scottish ship builders, and to the fact that on the English rivers the coal trade and various manufactures are carried on upon a scale of such magnitude as to withdraw attention from the fuller development of the ship-building industry for which the districts present such facilities.

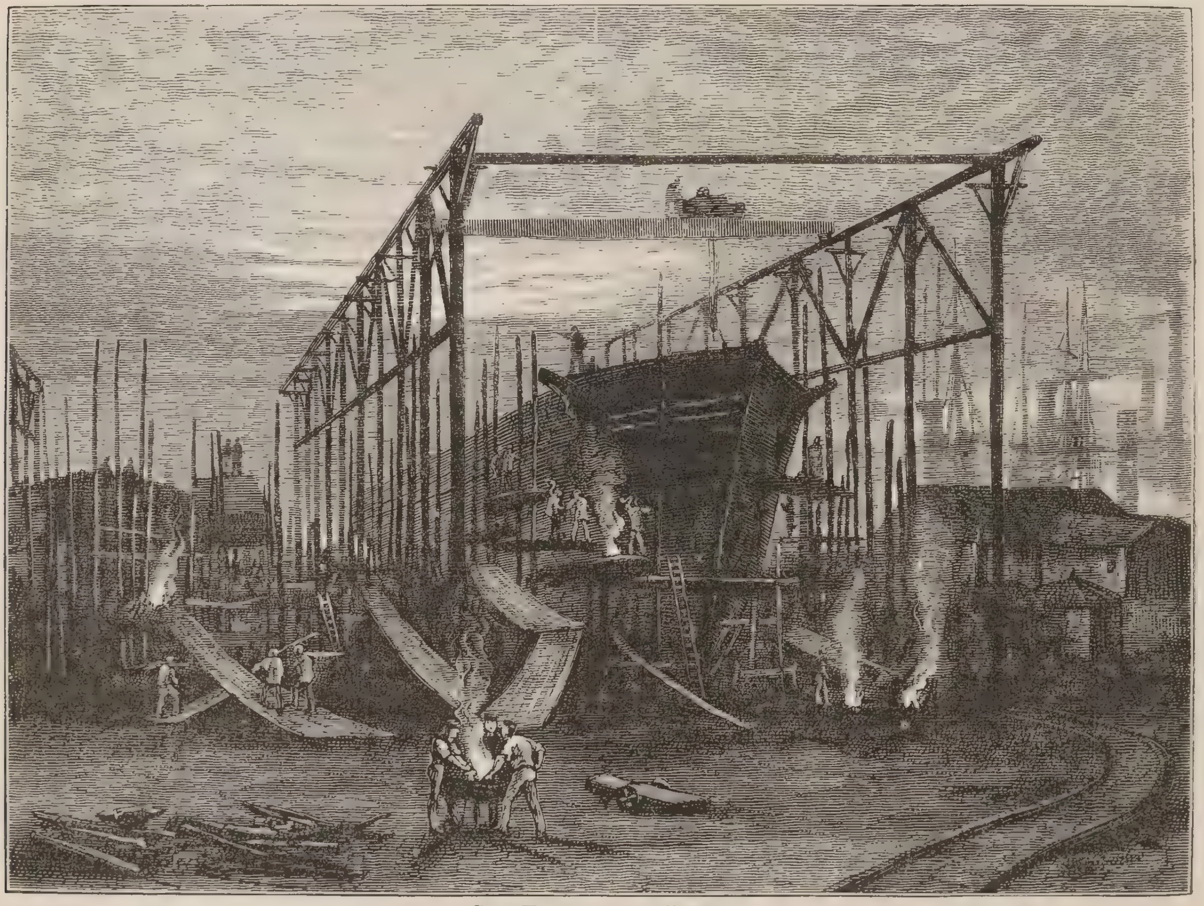
On the Mersey, ship building may be said to be overshadowed by shipping. Attention is attracted towards the forests of masts and miles of docks, and a visitor may easily overlook the ship-yards, although their work is very important and

extensive. Many well-equipped establishments exist, where the building or repair of ships and engines is carried on upon a large scale; but Liverpool no longer occupies so high a place as a ship-building port as it did in the earlier days of iron ships. From 20,000 to 30,000 tons of new ships is about the average annual production, and this is a very small percentage upon the tonnage owned in Liverpool or trading from that port. Liverpool ship-owners find it preferable to have most of their vessels built on the Clyde, or in the north-eastern ports. Of the ship-yards still at work, that of the Messrs. Laird is by far the most important. It was one of the earliest establishments in which iron ships were built, and the success achieved in this direction formed the foundation of a reputation that has since become world-wide. Ships for war and commerce, of all classes and all sizes, have been constructed by this firm; their yard contains all necessary plant and facilities for repairs as well as for building, and engines as well as ships are produced. Many of the ships built by the Messrs. Laird have attained great notoriety. From their yard issued the *Alabama*, to commence a career of daring and destruction; the ill-fated *Captain* was also built by them, in conjunction with Captain Coles; and the *Vanguard*, now lying in the Irish Channel, where she sank after collision with the *Iron Duke*, was their work. Three out of the four well-known Holyhead packets were built in this yard, and several ocean-going steamers of large size and high speed. While closely associated with the mercantile marine, Messrs. Laird's establishment is one of the great private firms which give valuable aid to the Royal Navy, and are capable of building iron-clad ships. Of late years, large repairs, as well as new work, have been done by the firm on several of H.M. ships, and the Royal Dockyards have thus been considerably relieved in times of pressure.

The Thames has been placed last in the list of centres of ship building because it has for many years past done the least work in producing new ships. A large ship-building trade still exists, but it is far less important than it was twenty years ago, and it is a sad sight to note deserted ship-yards, like that at Millwall, where once thousands of workmen were employed. Various causes have contributed to work this change. It is undeniable that the Thames was placed at a disadvantage, as compared with other centres of ship building, when the use of iron and steam-power became general; but its greater distance from the iron and coal districts will scarcely account for the rapid decay of ship building. The most influential causes of this decay were doubtless the frequent occurrence of strikes, and the maintenance of an artificially high rate of wages. Consequently the cost of labour on a ship built on the Thames was made much greater than it would have been on the Tyne or the Clyde, and this difference practically threw the Thames builders out of competition. A large amount of repairing work is necessarily done in the port of London, and this gives employment to large numbers of men; but several building-yards once famous are now closed, and there appears no prospect of the revival of ship building. A few first-class yards still remain at work. Of these, the chief are the Thames Iron Works at Blackwall, Messrs. Samuda's yard, and Messrs. Green's establishment. In the earlier stages of the iron-clad reconstruction, the Thames Iron Works held a high place. Some of the largest ironclads of the Royal Navy were built there, and the firm made a large quantity of forged armour-plates before the present mode of manufacture by rolling-mills had been developed. As a consequence, large orders have since been received from foreign Governments—Turkey, Germany, Greece, and Spain being amongst the number; and the Admiralty have entrusted important contracts to the company. War-ships have absorbed the principal part of their resources, but merchant-ships have also been built; and it was in this yard that the twin-ship *Castalia* was constructed. Messrs. Samuda also have, of late years, devoted most of their attention to the construction of ships of war for foreign Governments, having executed large contracts for the Germans, the Japanese, and the Brazilians. Messrs. Green are well known as ship-owners as well as ship builders, and the reputation which was won in the days of wood-built East Indiamen they are striving to maintain under the changed conditions of the present day, when iron hulls and steam-power are essential to success.

From this rapid survey it will be evident that the national resources for producing new ships are well proportioned to the magnitude of British shipping. From 400,000 to 500,000 tons of new ships are annually added to the Register, and a large amount of tonnage is built for foreign navies, as well as for the Royal Navy. In 1875 no less than 52,000 tons of shipping were built in the United Kingdom for foreigners; and private yards have built iron-clad war-ships for most of the maritime powers, including Germany, Russia, Turkey, Spain,

Portugal, Italy, Denmark, Greece, Brazil, Chili, Peru, and Japan. Unarmoured war-ships of all classes have likewise been constructed for foreigners, and very many merchantmen. Some of these products of British industry may be used against us in a naval war; in fact, this has already happened, for the Peruvian ironclad *Huascar*, which fought H.M. ships *Shah* and *Amethyst* in 1877, was built by Messrs. Laird. This fact has been urged as an objection against the policy of building foreign war-ships in this country; but there is a weightier argument in favour of non-interference with private enterprise. In times of transition, like the present, when great changes are being rapidly made in the types, armour, and armament of war-ships, the first importance attaches to the possession of vast ship-building resources, available at short notice to produce selected classes of ships. But these resources lie in the great private establishments, equipped with all the necessary special appliances; and these establishments, with expensive plant, some of which is not required for mercantile ship building, could scarcely maintain their position apart from foreign patronage. In short, foreign patronage, under ordinary conditions, helps to support and extend our ship-building resources, which in time of war can readily be made available for the national defence. The average addition made annually to the Royal Navy is about 20,000 tons: about two-thirds of this tonnage is usually built in the royal dockyards, and one-third in private establishments. The production of all the dockyards, in time of peace, is, therefore, inconsiderable when compared with that of a few of the largest private ship-yards; and it is to the latter that we have to look chiefly for new ships in war-time. Then the normal addition to the fleet can be trebled or quadrupled with ease. In 1855, for instance, no less than 75,000 tons of new ships were added to the navy: in 1861 about 56,000 tons were built; and in case of emergency much more could now be done than has ever yet been accomplished in rapidly strengthening our naval force.



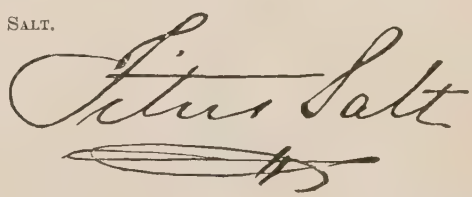
Ship-Yards on the Tyne.

WOOL AND WORSTED.—III.

ALPACA—THIRD PAPER.

By William Gibson.

"TAILLEFERS," says Thomas Carlyle, in one of the most remarkable passages of "Past and Present," "at the end of the campaign, did not



Portrait and Autograph of Sir Titus Salt.

turn off his thousand, but said to them—'Noble fighters, this is the land we have gained; be I Lord in it—what we call *law-ward*, maintainer and *keeper* of Heaven's *laws:* be I *law-ward*, or, in brief orthoepy, Lord in it, and be ye loyal men around me in it; and we will stand by one another, as soldiers round a captain, for again we shall have need of one another!' Plugson, buccaneer-like, says to them—'Noble spinners, this is the hundred thousand we have gained, wherein I mean to dwell and plant vineyards; the hundred thousand is mine, the three-and-sixpence daily was yours. Adieu, noble spinners: drink my health with this groat which I give you over and above.' . . . The vulgarest Plugson of a master-worker who can command workers, and get work out of them, is already a considerable man. Blessed and thrice-blessed symptoms I discern of master-workers who are not vulgar men; who are nobles, and begin to feel that they

must act as such; all speed to these—they are England's hope at present." That passage very fairly sets forth the distinction between a selfish employer who, in his relations with his servants, acts on the principle of mere supply and demand, as contradistinguished from such a "captain of industry" as Sir Titus Salt. Workmen will be very much like their masters. Let the one be selfish and grasping, the others will be slipshod and idle. They consider that it is quite as fair to shirk duty on their side as it is for him to screw more than the wages-value out of them. It is a fair fight. Given a factory clean and healthy, and a master who has some consideration for his workers, there shall be no unnecessary waste either of time or of material: given a master who thinks any shed good enough for work-people, and that his duty to them is done when he pays their wages, the machines will be rusty, probably there will be endless waste, and the work done will only be of moderate quality at the best. These reflections bear directly upon the question in hand. Those who have had any experience of factory operatives and factories would almost be able to predicate from the appearance of a mill the character of master and man. The works at Saltaire are an example of the proposition. Whoever has gone through them must have noticed the scrupulous cleanliness everywhere, the entire want of waste about the looms, the comparative absence of dust in the vicinity of machinery simply of a purifying character, the lack of untidiness in the sorting and picking departments, and the purity of the air and brightness of the sunshine in all parts of the buildings.

Among the many industrial piles in the kingdom, that at Saltaire is one of the most notable. Exteriorly, it sins against the dogma of Ruskin, that the useful should not be ornamental, for, like all the other buildings in the place, it is in the Italian style of architecture, and remarkably handsome and massive in design. The main blocks are in the form of a T, enclosed in a square of outer offices, warehouses, and loom sheds. Built throughout of light-coloured stone, they have the cleanly appearance which bricks can never attain, and with their tall chimney shooting aloft like a bell-tower or Italian campanile, they form a striking feature in the landscape.

Covering an area of 10 acres, these works have a flooring space of 55,000 square yards. The main blocks rise to a height of 72 feet, and are divided into six storeys. The south front is 575 feet long, and the warehouses, which run at right angles to it, 330 feet. The engine houses stand at the junction of the two blocks, and are fitted with five engines—four horizontal, on the Corliss principle, with Mr. Spencer's improved expansion motion, nominally of 100 horse-power each, but capable of being worked up to 1,700; and one vertical, of 360 horse-power. The motive power for these splendid specimens of engineering skill is obtained from sixteen boilers, and they drive some three or four miles of shafting, as well as innumerable implements of the most curious, costly, and wonderful character. When it is stated that 2,400 tons of stone were used in the bedding of the engines, that the walls of the main buildings are some five feet thick, and that the floors rest upon arches of hollow brick, supported by iron beams and ornamented iron pillars, some idea of the substantiality of the whole pile may be obtained. At one end of the south front are weaving sheds, in which 1,200 looms are daily at work; at the other, a combing shed, 210 feet long and 112 feet wide, besides sorting, drying, dyeing, washing, reeling, and packing rooms. The offices, which have a frontage of 240 feet, run along the side of the turnpike road, and in the centre of these is the great gateway, or main entrance. The top room on the south front runs the entire length of the building, and is probably the largest in the world; while over the warehouses has been constructed a huge water tank, capable of containing over 70,000 gallons of water. To complete the description, note must be taken of the gas works, which not only supply the factory, but the town, the people paying for it only 3s. 6d. per 1,000 cubic feet. The chimney, as has been said, rises to a height of 250 feet, and is 36 feet square at the base, while a splendid stone bridge, or rather series of bridges, has been constructed along the high road over the railway, the canal, and the river. The site of these works has been admirably chosen. One side of the square is flanked by the line of the Midland Railway Company's system, another runs along the Leeds and Airedale canal, while the main road from Bingley to Baildon skirts a third. So that it is equally accessible by road, river, or rail. The rooms in the interior are lofty, light, and well ventilated; and the walls, instead of being covered simply with glaring whitewash, are tinted, and have a very pleasant appearance. Let us now see what manner of work goes on inside the buildings.

Before the alpaca fleece is transformed into cloth, it goes through no less than fifteen distinct processes, and the machinery employed in these is simply unique. The wool is disembarked wholly

either in London or Liverpool. It is made up in small bales—or "ballots," as they are technically called—each containing seventy pounds weight of fleeces. The Midland and other railways bring it by a private line under the arches on which the main buildings of the factory at Saltaire are erected, and it is hoisted direct from the trucks to the receiving room. Thence it is taken to the sorting department, where the different qualities, colours, and lengths are deftly divided. This is rendered necessary from the fact that the fleece of one sheep is not of the same quality throughout, and sometimes one "ballot" contains the fleeces of all four species of the llama. Sorting is an operation requiring great experience, and so skilful have some of the workmen become that eye and hand are keen enough to discern differences which are only apparent to the uninitiated by the aid of the microscope. With unerring skill, the wool sorter divides the alpaca into from six to sixteen different classes and qualities, according to the variety of the material that lies strewn before him on tables breast-high, casting each handful or two rapidly into its proper basket around him on the floor. On its arrival at the works, the alpaca is generally in so filthy a condition that nothing further can be done with it till it has been thoroughly washed. In ordinary factories, old-fashioned machines are still in use for this purpose. At Saltaire, however, new and much more expeditious implements are at work. Instead of beating the wool with a club-like wheel, in the tub containing the cleansing liquor, a sort of rake-wheel is employed, which not only tears the matted alpaca asunder, but much more thoroughly exposes every fibre to the action of the soap and water. From the washing room the alpaca, now bright and clean, though wet, passes to the drying machines. Having been partially dried in the huge dryers which, whirling round at an incalculable velocity, drive off the moisture by centrifugal action, the wool is passed over a series of steam cylinders, and finally placed on a winnower, from which it emerges "dry as bone." It is now ready for picking or plucking, which is done by its being passed between two cylinders armed with short iron teeth slightly bent. By this means the matting not taken out in the washer, the burrs, and other foreign materials that cling to the wool, are removed. The fibres, which were inextricably mixed, are roughly prepared for the combing process by being next pulled somewhat straight. These four are merely preliminary stages in the transformation of the raw into the finished product.

Combing was formerly a long and arduous part of the work of cloth-making, since the fibres of the wool had to be laid straight by being pulled through combs armed with one, two, or three rows of iron teeth. One of these tools, having been heated, was secured to a post spikes upwards, a certain quantity of wool placed upon it, and, by means of another comb, passed backwards and forwards till it was ready for drawing and spinning. What was so slow, however, was subsequently done much more rapidly and efficiently by machinery, which was constructed to imitate as closely as possible the hand process. The patron saint of the combers is St. Blaize, Bishop of Sebasta, in Cappadocia, probably because his flesh was torn from his limbs with hot iron combs. A legend runs to the effect that he discovered the means of tearing out wool, but this is probably apocryphal. By hand, a considerable waste was occasioned, but by the perfected machines used at Saltaire, which are an adaptation of the famous invention of Heilman, with Lister's screw-gill improvements, the waste or "noil" is very slight.

These delicate and intricate machines, roughly speaking, consist of three parts: the feeding portion, which carries portions of the plucked wool forward to a revolving comb, some of which have seven or eight "pitches" (*i.e.*, rows of spikes or teeth); and the combing apparatus, which straightens out one portion, and gives it up to the third part of the mechanism, whose duty it is to lay it in bands or "slivers," and carry it away for the next operation. The four chief patents are those the essential parts of which are presented in the accompanying diagrams.* Fig. 1: This machine was an improve-

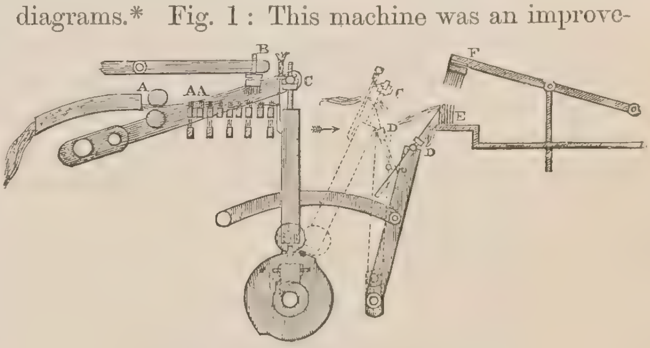


Fig. 1.—Lister and Donnithorpe's Machine.

ment on that of Heilman, and its advantages are to increase the quantity of the work performed in a given time, as well as the range of material which can be manipulated. The feeders A, and the screw gill A A, carry the prepared wool into the machine

* From the article on "Woollen and Worsted Manufactures," 'Encyclopædia Britannica," 8th edition, by permission of Messrs. A. and C. Black.

and comb it as it goes. The nippers C detach a portion, which is brushed by B, carried forward by the porter-comb D, and delivered to the circular combs at E. At the instant it is so delivered, another brush, F, presses the portion of wool into position for being properly drawn off, and thus it passes into the revolving drum, and is delivered a

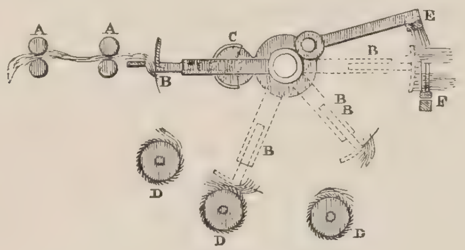


Fig. 2.—Preller's Machine.

perfect "slub" or band. The other machines are very much similar. In Preller's (Fig. 2), A A are the feeders; B, a receiving arm, is a comb which carries the tuft of wool at the receiver F, through the card cylinders D D D, by which its tail end is effectually combed. Crabtree's machine (Fig. 3) simply varies the taking mechanism.

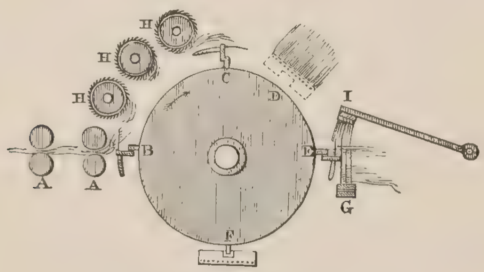


Fig. 3.—Crabtree's Machine.

Here, instead of one arm, there are four, B, C, E, and F. The feeders are at A A, which give the wool to a series of card cylinders, H H H. As the large drum in the centre of the diagram revolves, the wool is taken from carder to carder till it arrives at E, where it is caught by the receiver G, pressed down by the brush I, and carried away a perfectly combed

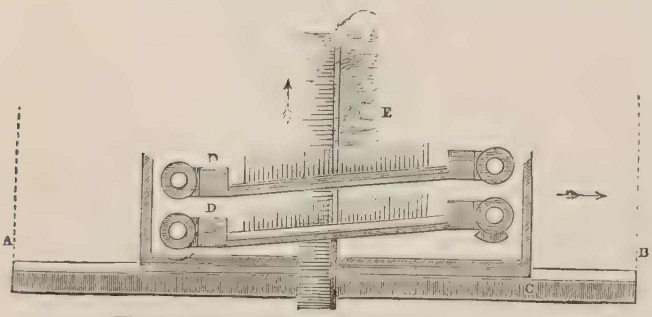


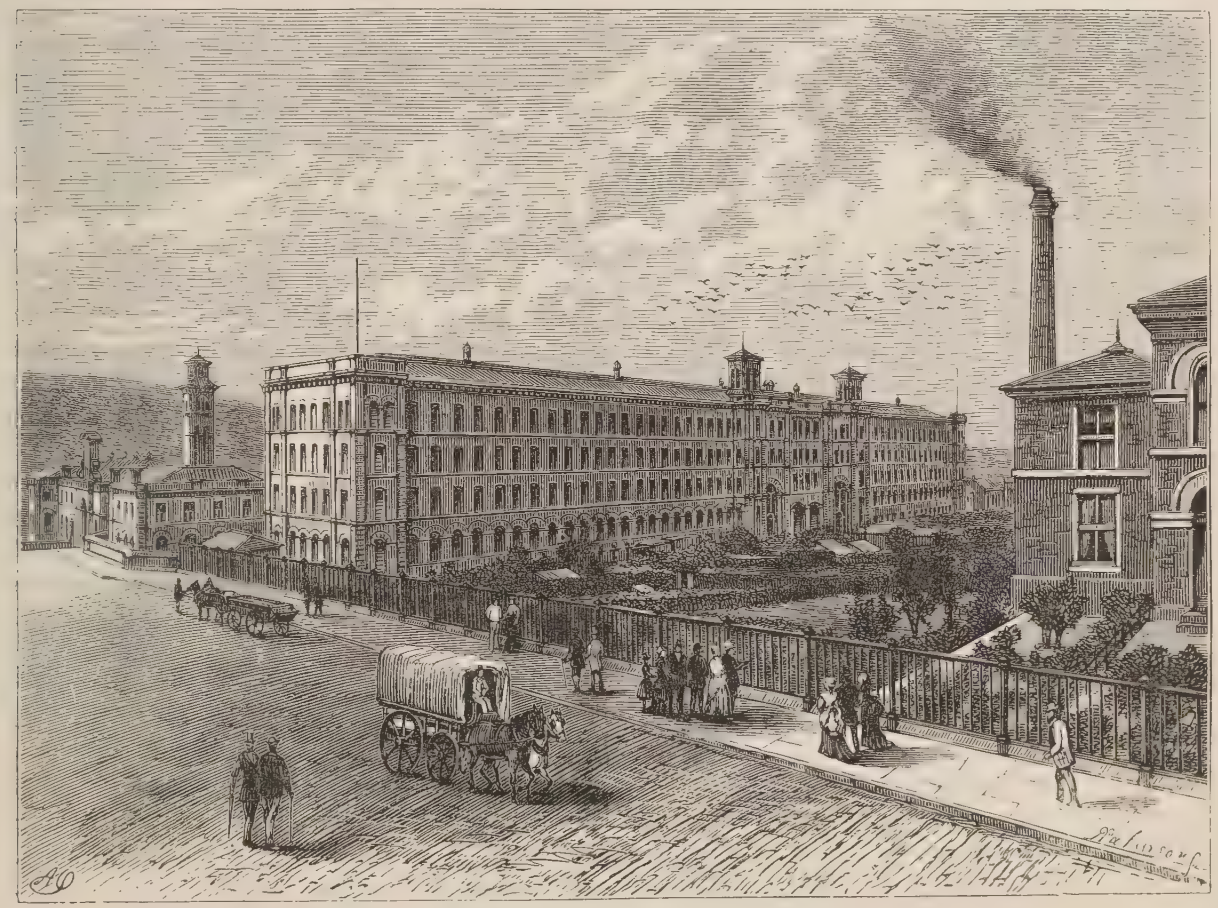
Fig. 4.—Ramsbotham and Brown's Machine.

"slub." The last machine (Fig. 4) is the patent of Messrs. Ramsbotham and Brown. The chief novelty of this implement consists in filling the fibre into the teeth of a receiving comb across a screw gill, the teeth of one standing at right angles to the other. The gill D D is made to slide on the bed C. When close to the end of the slide at A, a catch-comb suspended in front, but not seen in the diagram, drops into the end of the fleece, and by its receding motion carries it to the outer edge of the receiving comb E, and delivers its load from one end of the gill bar to the other in consequence of its circular motion. These gill bars, being inclined to the plane of their motion, cause portions of the wool so supplied to overlap each other, and thus it is capable of being drawn out more easily. The receiver revolves vertically in the direction of the arrow (see fig.), and by this process the "noil" is not, as in the other machines, pressed into a hard mass. All these appliances, it will be seen, effectually comb the wool piecemeal, yet give it up in a continuous "slub," and with much less waste than was necessitated by the ordinary hand comb. All have their advantages, but those of Crabtree and Ramsbotham are held in great repute by very good judges. Sir Titus Salt's "combers" are wonderfully ingenious and delicate, and the adaptation of these machines to the character of the alpaca was the great difficulty which this "industrial chief" had to surmount. The combs, as has been already said, are of a much deeper "pitch," and, as the wool is more delicate in fibre, they are finer in workmanship and nicer in operation than the ordinary implement used in the manufacture of wool. These machines do as much work as 150 hand workers, and at one-sixth of the cost, while the quantity of waste is infinitesimal as compared with the manual process, and the work much more efficiently accomplished. A stone of alpaca, after being combed, yields on an average about eleven or twelve lb. of "top" or spinable "sliver," and two or three of "noil," the remainder representing the dust and foreign substances with which the product was charged on its arrival at the works.

"Slivering" is the next and, at Saltaire, one of the most important of all the operations, for by this process the beautiful combinations and admixtures of natural colours necessary in plain undyed cloth, are obtained, and it is one confined to this material. The "slivering" machines, if not the invention of, are at any rate solely possessed by, Salt and Co., and the work they do is almost incredible. It is not given to the general public to know the mechanism of the "slivering box," but it may be called a cylinder, fitted with Lister's

screw gills, into which the various natural-coloured alpacas are put, inextricably mixed, and drawn ready for the "carders." It was only by long experience that the proper quantities necessary to produce the various shades, and the length of time requisite for these extraordinary machines to do their work, were reduced to a science; and when we recollect the immense numbers of shade combinations which are constantly woven, the miracle of the slivering box by no means lessens. It has been computed that, in producing some of the shades, the individual fibres in a given quantity of wool change places no less than 20,971,520 times before the requisite mixture is obtained. By means of the screw-gill machine attached, the alpaca as it issues from the slivering box is partially combed out, and passed on as rude "slubbing" to the carding machine. It is generally found necessary to pass the material once or twice more through the "combers" before it is sent to the drawing machines; and, after passing through this second combing, it is bright, glittering, and variegated, as we see the warp and woof in the finished fabric.

These operations, though generally called "dirty," are productive of no dirt in the different departments at Saltaire. In fact, the visitor to the works is struck so far with the absence of dirt, dust, and din. Whatever dirt there may be is carefully kept out of sight; and as the machinery works in exquisite regularity, there is not that bewildering turmoil which is such a drawback in factories generally. One observes, too, that the work-people are invariably clean, assiduous, and attentive. Not staring at strangers, gossiping with their neighbours, or stopping work to look at new-comers. The golden rule—"One thing at a time, and that engaged in with all the heart"—evidently prevails here.



The Mill at Saltaire. (*From a Photograph by Mr. E. Wormald, Leeds.*)

Drawing is only a finishing of the previous process, and is so called because it "draws" fibres of the wool out straight, and perfects the "sliver" or band ready for roving. The usual custom in the wool trade is followed at Saltaire. The "slivers" are placed upon an endless apron attached to each of the six frames drawn through sets of "screw gills," and between pairs of rollers into the coiling

can, where they are slightly twisted. Eight double slivers are then passed through similar "drawers," and proceed to the third set of machines, provided with two large spindles, which further "slub" or twist the "slivers." These are carried forward to a fourth machine provided with four spindles, till at last they are ready for roving. That process is simply a stage in advance of drawing. There are eight machines in all, similar to each other, and each provided with eight spindles, which "slub" the loose threads still tighter, and they at once proceed to the "spinning-jenny"—although, were Hargreaves to be resuscitated in these days, he would scarcely know the modern "jenny." His machine was slow and rude compared with ours, and his utmost number of spindles has been more than quadrupled upon each machine.

There must have been something provocative of thought in the occupation of the hand-loom weaver in olden times—the early years of this century are far behind us—for old-fashioned weavers were shrewd men. It is Robert Buchanan who says—

> "I thought and thought, and thick as bees the thoughts
> Buzzed to the whuzzle-whazzling of the loom."

But, except in remote corners, all that is done away, and in Saltaire weaving is most prosaic, though far more expeditious than was the old process. And yet, as one looks round the immense shed in which 1,200 or more double looms are turning out 30,000 yards of cloth every day, one cannot but be struck with the "march of civilisation." No less than 5,688 miles of alpaca stuffs are turned out of these premises every year—enough to reach from England to Peru, whence comes the raw material. And in some respects the weaving sheds are the most attractive part of these marvellous works. Everything here is stir and life. Looms of the newest pattern, clean, bright, and pretty, upon which all kinds of cloth are being rapidly woven—virgin white, mixtures of all the shades of the dove's throat, flowered fabrics, dyed stuffs, and so forth—while the pretty faces, tidy dress, and general smartness of the weavers lend a charm to all that is found in no other department. A good weaver here can turn out three "pieces" (120 yards) per week; and of inferior and coarser material four or five pieces. The names of the various materials woven from alpaca make a long list. There are lastings, crapes, Orleans, casmetts, twills, French figures, Parisians, damasks, camlets, merinos, challis, mousselaine de laine, cobourgs, paramattas, shalloons, duroys, serges, taminets, khybereens, poplins, bombazines, figured and plain satteens, cubicas, fancy waistcoatings, robes for ladies (plain and mixed), lustres, mohairs, figured alpacas, and many others. One thing is noticeable in the loom sheds, as elsewhere throughout these works—the shafting is nowhere visible, nor those long ugly lengths of belting that so mar the *coup d'œil* in most factories. All the shafting is under the floors, and what belting is required is not paraded to the visitor, but glides slily to its appointed place.

When the cloth leaves the loom, it is passed to the "taker-in," who examines the workmanship, and notes the defects, if any exist. These have to be darned carefully by women specially employed, and, having finally "passed muster," are sent to the dyer if they are white, or to the finisher should they be mixed or figured. The finisher is an important personage in the manufacture of alpaca. It is his business to singe all the slight bits of wool that have not been properly spun, to steam the pieces so that the cloth may not shrink afterwards, then to stretch, press, and calender it to improve its gloss. Having successfully performed all these operations, he hands it over to the warehouseman, who folds it neatly, packs it in convenient wrappers, and sends it down, by means of the hoists that brought the dirty, crude alpaca wool into the works, to the railway trucks, that speedily carry it to all parts of the kingdom, and to the various ports whence it is shipped to every quarter of the globe. Many merchants buy the pieces as they come from the loom, and dye them at home, but Salt and Co. are prepared to dye and finish before the cloth leaves the works. In fact, it comes in fleece at one end of this remarkable establishment, and goes out a beautiful marketable article at the other. A complete, self-contained, wonderful industrial organism is the Saltaire mill, and it may be said that the bulk of the alpaca that is imported into this country is manufactured here.

We have endeavoured to give an outline of the history of this notable product, and the man who, by his unaided ability, discovered the means by which it might be manufactured, the processes through which the wool arrives at the perfect article, and the town in which its fabrication is carried on. Naturally, much which might have interested the adept has been passed in silence; but perhaps enough has been said to give the general reader the salient facts connected with this branch of English industry, which a few years ago was almost unknown, but which to-day stands in the front rank of the GREAT INDUSTRIES OF GREAT BRITAIN.

IRON AND STEEL.—IV.

THE CUPOLA FURNACE AND "CASTINGS."

By William Dundas Scott-Moncrieff, C.E.

Before going on to speak of malleable iron and the various methods employed for producing it, we propose to devote a paper to the subject of cast iron and castings. It has already been explained that the Blast Furnace is used solely for smelting and purifying the ores, and that this is generally done upon a very large scale. There is, however, another form of furnace, which is almost identical with the blast furnace in many respects, but which is only used for melting the iron that has been previously obtained from the larger apparatus. This is called a Cupola Furnace, and is in daily operation in every establishment that requires "castings." Even in country villages it is a common adjunct to the local engineering work which supplies ploughshares and pruning-hooks, and the various forms of machinery which are now almost universally used in agriculture. Except that it is less elaborate, the cupola furnace is simply a blast furnace constructed upon a diminutive scale. It is built of fire-bricks bound together by bands of iron to enable it to resist the strains that arise from excessively high temperature, and is supplied by a blast of air from a fanner. There would, no doubt, be a considerable saving in the amount of fuel required for melting a given amount of iron if the hot blast were employed. But as the furnace is generally in use for only part of a day, during which the casting is done that is required for carrying on the construction of the various pieces of machinery in process of being completed, there could not be much, if any, economy in using additional fuel or kindling additional fires for the purpose of keeping the blast at a high temperature. Hence the blast is generally cold. Whether rightly or not, there is still a prejudice in favour of cold-blast iron, and "No. 1 Cold Blast" is a common stipulation in specifications of machinery requiring cast iron for their construction. As the whole height of the furnace to the opening at which the materials are thrown in is seldom more than fifteen feet—instead of eighty, as is common in blast furnaces used for smelting crude ores—the "burden" of the charge is, of course, very much lighter, and the blast required is correspondingly reduced. This renders it unnecessary to employ the expensive and elaborate machinery of the blowing engine required for smelting ores, and a simple fanner is generally used. It consists of a circular casing inside of which there is a fan made with arms or vanes that allow the air from the outside atmosphere to enter at the centre, and which revolve so rapidly that a current is produced. The air is whirled out to the rim by centrifugal force, and is afterwards directed to the bottom of the furnace by means of a pipe. All the operations of smelting the iron in one of these small cupola furnaces are correspondingly simple. In a large blast furnace the process of "blowing-in" requires to be carried out with the greatest care in order to avoid the choking up of the interior by the materials getting bound together in a mass through which the blast is unable to pass, and which it would be almost impossible to remove without taking the furnace to pieces if allowed to cool and harden. The plan that was once adopted for "blowing-in" blast furnaces was what is called "scaffolding." The fuel was first supported upon bars arranged in rows on a level with the top of the dam-plate until the molten metal began to appear, when the bars were removed so as to allow the "charge" to descend upon the hearth from above, whereupon the blast was turned on in full force. Nowadays, when a furnace is "blown-in," it is generally done by arranging about a ton of old timber in the bottom of the furnace to a height of three or four feet and then adding about six tons of coke. Further charges are then laid on above this, consisting of coke, limestone, and a very light "burden" of ore, the furnace being in this way charged to about one-third of its height. The wood is then ignited, and when the fire has had time to ascend, other materials are added until the heat is sufficient to admit of the addition of more ore. When this begins to melt, the blast is turned on, very gently at first, but not with its full force until a few days have elapsed, when it is expected that the operations can be carried on with greater freedom. Several weeks are often allowed to pass before the charging and the blast are both carried out to the maximum capacity of the furnace. It can readily be understood from this description how much care is necessary in "blowing-in" a blast furnace, and how much loss of time and money would arise from the materials collecting into masses

called "scaffoldings," which prevent the blast and heat from reaching the materials at the top. All this is, of course, very much more easily accomplished in a cupola furnace, where a little firewood and coke is enough to set the operation going, and in which the furnace does not require to be "blown-in" for more than an hour before the cast iron is sufficiently fused to admit of its being poured out into moulds.

Before leaving this part of the subject, it may be interesting to the reader to know something about the causes of explosions that sometimes occur in blast furnaces, accounts of which, under the heading of "Accidents," not unfrequently appear in the newspapers, and which are generally accompanied with much suffering to the injured, from the molten iron being scattered about in all directions. It was explained in a previous paper that the hot blast from the blowing engines is conveyed in pipes to the bottom of the blast furnace, and that it is directed upon its seething contents by means of a nozzle, called a "tuyere." In order to protect these nozzles from the intense heat, which would very soon melt them away, they are surrounded by cold water, which is kept in constant circulation, and which renders them comparatively cool. Almost all the explosions that have ever taken place in blast furnaces are traceable to a leak in this circulating apparatus, which allows water to be injected into the furnace along with the blast, and leads to such a sudden development of steam that an explosion follows, often throwing out great masses of molten iron and cinders, and destroying any unfortunate workmen who may happen to be in the way. It appears, however, that leaky nozzles are so common, that if the mere injection of water into a blast furnace were invariably followed by an explosion, such accidents would be much more frequent than they really are. This has led some ironmasters to conclude that it is not the presence of water, but the wet surface of a nozzle which has been melted off and fallen into the molten metal, that causes an explosion; for experience has proved that a little scrap of wet iron, if forced amongst a molten mass, will be sufficient to cause a greater catastrophe than water. It is this fact that makes plumbers so cautious when they are pouring molten lead into a recess. Any moisture on the surface that comes in contact with the metal is converted into steam so instantaneously, that carelessness not unfrequently entails upon the artisan the penalty of loss of eyesight from the effects of the explosion. In blast furnaces accidents sometimes arise from explosive gases getting into the pipes which lead from the furnace to the blowing engines, and these create immense damage when they are exploded by ignition. The following is the account of another kind of accident which occasionally occurs in connection with blast furnaces. It is given by Mr. Menelaus, the manager of the Dowlais Iron Works.

"Mr. Truran's death happened in the following way:—A portion of the ground in front of our old works' furnaces is an old cinder-tip, where the cinders from the furnaces had been thrown when they were originally blown-in. Through the cinder-tip we made a large brick culvert, for conveying the waste gases to the forge boilers. We find these culverts are cheaper than pipes, and on the whole they answer well. Mr. Truran's office was built upon the old cinder-tip, about from ten to fifteen yards from the side of the culvert. A few days after the gas had been turned through the culvert Mr. Truran went to his office about midday. In the evening, when he did not return home as usual, his family made search for him, and he was found lying dead on the floor of the office. He had been sitting at his desk with some drawings before him, and he had evidently, from having been overcome by the gas, fallen from his seat. There could be no doubt that he was poisoned by the gas. I went with the jury to the office, which had been locked up from the time of his death, and the smell of the gas was quite perceptible, and the atmosphere of the office so disagreeable, that we were obliged at once to get into the open air. As the forges are below the level of the furnaces, the gas in the culverts is under considerable pressure, and no doubt had escaped through the new brickwork and the loose cinder-tip into the office—how, there is little or no knowledge."

Many experiments have been made upon the action of carbonic acid and carbonic oxide gases in their poisonous effects on animals, and the conclusions to which eminent physiologists have come, are that the fatal accidents which have happened in connection with blast furnaces have arisen from the presence of the latter gas, which is said to be destructive to life when mixed with common air in the proportion of six parts in one hundred.

Let us, however, now return to the subject of the cupola furnace and castings. When speaking about the fuel that has been used at various periods for the production of the different forms of commercial iron, it was pointed out that improved methods of treating coal were forced upon inventors

Running the Molten Iron into the "Pigs."

and manufacturers from the increasing scarcity of timber available for making charcoal, and that the prosperity of the iron trade hinged upon their success. A name that is intimately associated with those improvements was, however, left unmentioned. After several failures on the part of persons who obtained patents for the use of "sea-coale" or "pit-coale" during the reign of James I., in the early years of the seventeenth century, Dud Dudley of Tipton took up the subject, but after having worked at it under endless difficulties and litigation during the greater part of his life, it seems to have gone out of sight, and no great improvement appears to have taken a permanent hold upon the industry until the time of Abraham Darby and John Thomas, whom we have already incidentally alluded to in this series. Dud Dudley was the fourth natural son of Edward, Lord Dudley, by Elizabeth, daughter of William Tomlinson, of Dudley. He was born in 1599, and died at the age of eighty-five. He published a book in 1665, called "Dud Dudley's Metallum Martis; or, Iron made with Pit-Coale, Sea-Coale, &c., and with the same Fuell to Melt and Fine Imperfect Mettals, and Refine Perfect Mettals." He left Balliol College, Oxford, in 1619, to take charge of his father's iron works, at Pensent, in Worcestershire, which consisted of one furnace, presumably a blast, and two forges, all working with charcoal. It seems quite certain that his attempts to substitute coal for charcoal were so far successful that he brought upon himself the rivalry and ill-will of other manufacturers, whose iron he was able to undersell. Curiously enough, though the great changes in the value of money which have since taken place render the comparison somewhat inexact, the prices at which he sold his cast iron and iron bars were very much the same as those that ruled in our own markets within the last three or four years—namely, £4 per ton for pig-iron, and £12 for malleable bars. After many difficulties and disasters—one of which was the washing away of his mill by "the great *May-day flood*"—he became connected with two partners in a furnace near Bristol, but soon found himself entangled in a chancery suit, he, on his part, alleging that they had cheated him. In 1657 the practice of using coal seems to have been entirely abandoned; and Dud Dudley during several years suffered in his business from being a Royalist. After being refused a further extension of his patents, which he asked for on the day of Charles II.'s landing at Dover, on 26th May, 1660, he appears to have abandoned his inventions altogether. An account of the iron trade in the Forest of Dean was written by Henry Powle, in 1676, and from this we gather that it was carried on with charcoal as the only fuel.

It is after a lapse of about sixty years that we come upon the Darby family, who may be said to be the fathers of the modern practice of "casting." Dr. Percy, to whose researches every writer in metallurgy must be deeply indebted, did much for the history of the iron trade in this country by obtaining a record of the Darby family from its representative, Mr. Abraham Darby, of the Ebbw Vale Iron Works. The Colebrook Dale Iron Works, with which their names were so long and honourably associated, belonged, it appears, at the time of the battle of Worcester (September 3rd, 1651) to the family of Wolffe of Madeley—"the same Wolffe who after the battle sheltered the royal fugitive in a barn, while the soldiers on the king's track were regaled by Mrs. Wolffe with bread, cheese, and ale." The next owner was a Mr. Fox, in whose hands the furnace was blown up by an explosion arising from the water getting into it from a burst dam. He, by the way, went to Russia with Peter the Great. In 1670 John Darby occupied a farm called the Wren's Nest, in Worcestershire, and his son Abraham, after having carried on the business of a malt-miller at Bristol for about six years, went over to Holland and "engaged Dutch brass-founders to return with him to England." With other partners he established the Baptist Mills for casting brass, and took the management himself. We cannot do better than quote the rest of the narrative as Dr. Percy obtained it from Mrs. Darby:—

At this time a Welsh shepherd-boy, named John Thomas, succeeded in rescuing a flock of his master's sheep from a snow-drift; and later in the spring of the same year, during heavy rain and the melting of the snow, he swam a river to fetch home a herd of mountain cattle. These he collected and drove to the river, but the ford had now become a boiling torrent. He nevertheless crossed it on the back of an ox, and brought home the whole herd in safety. As a reward for his courage, his master presented him with four of the sheep he had saved. He sold their wool in order to buy better clothing for himself, and afterwards disposed of the sheep, so that he might obtain money wherewith to travel to Bristol and "seek his fortune." Afraid of being pressed for a soldier if found in Bristol out of place, as it was then the time of the Duke of Marlborough's wars, he requested his master to recommend him as an apprentice to a relative, who was one of the partners of the Baptist Mills. The boy was

accordingly sent into the brass-works, until he should procure employment. As he was looking on at the Dutch workmen trying to cast iron, which they did at the suggestion of Abraham Darby, he said that he "thought he saw how they missed it." He begged to be allowed to try, and he and Abraham Darby remained alone in the workshop the same night for the purpose. Before morning they had cast an iron pot. The boy Thomas entered into an agreement to serve Abraham Darby, and keep the secret. He was enticed by the offer of double wages to leave his master; but he continued nobly faithful, and afterwards showed his fidelity to his master's widow and children in their evil days. From 1709 to 1828, the family of Thomas were confidential and much-valued agents to the descendants of Abraham Darby. For more than one hundred years after the night in which Thomas and his master made their successful experiment of producing an iron casting in a mould of fine sand, with its two wooden frames and its air-holes, the same process was practised and kept secret at Colebrook Dale, with plugged key-holes and barred doors.

Darby's partners were so dissatisfied with the expenses he was incurring in his experiments, that they came to the conclusion that he "had lost his judgment, and was squandering their money." It ended in his taking a lease of the furnace at Colebrook Dale, and he and his faithful servant, John Thomas, went there in 1709. He died after a successful conduct of the new business, the increasing value of which may be judged from his having sold one share of $\frac{1}{16}$th of the works for £330 in 1715, which was bought back in 1758 for £1,150. His widow and children were defrauded after his death by a brother-in-law, and befriended by John Thomas. Abraham Darby left a son of the same name, who was born in 1711, and took charge of the works in 1730. It was shortly after this period that the experiments referred to in our last paper were made, when Darby fell asleep on the top of the furnace, after six days and nights of watchful labour, and when he discovered the use of coke as a substitute for charcoal.

There can hardly be any apology needed for giving this story at so great a length, as it is perhaps the most romantic in its own way in the whole history of the iron trade.

We have already occupied so much of this paper, that there is little space left for a description of the method of producing iron castings, which are as various as the infinite variety of the purposes to which they are applied, and so we shall merely introduce the subject in a general way, and leave much of it over for a more detailed description. The molten iron that comes from a blast furnace is "cast" into pigs; and in many cases there are large sheds, called casting-houses, erected in the front of the furnace to protect the workmen from the weather, though these are very commonly dispensed with altogether. The floor of the casting-house, or the open space in front of the furnace, is laid with a deep bed of rough sand, which is raked and levelled before each "cast," and then impressed with a "pattern" or "print" of the "pig," as shown in the wood-cut (p. 113). There is a gentle slope that allows the molten metal to run along the channels, which are arranged so that it can be turned first into those farthest from the furnace by means of an iron spade. The long channel at the side communicates directly with the tapping-hole of the furnace from which the metal issues, and by plugging up the entrance to the transverse channels or "sows" that are nearest the furnace, and then removing the obstruction as each set of "pigs" is filled, all the moulds are completely flushed with molten iron to the level of the sand bed, where it is allowed to cool. After the iron has become hardened, the "pigs" are "broken" off at their junction with the "sow," and are ready for the market, the lower part bearing the impress of the brand and quality, which had been stamped in the sand by the "print." In drawing off the melted iron from an ordinary cupola furnace, much the same sort of plug is used as in a blast furnace—viz., a lump of clay, mixed with coal-dust, which is put upon the end of a rod with a flattened point, and thrust into the tapping-hole, when the flow of metal requires to be stopped. In removing the plug, which soon becomes hardened by the action of the intense heat, a rod with a sharp point is hammered against it, readily breaking it in pieces, and allowing the metal to escape as before. The ladles used for conveying the molten metal from one part of the foundry to another are of various sizes, according to the quantity required. When small castings are being made, these ladles are no larger than can be conveniently carried by two men, one of whom has the charge of directing the metal into the mould, and the other carries up and steadies the unforked end of the bar, into the middle of which the ladle or pot is inserted, as shown in the wood-cut on the next page. In order to protect the "ladle," which is generally made of cast iron, from the heat of its molten contents, it is covered inside with a layer of

sand and clay, which is plastered on the surface to a thickness of about an inch, and then slowly dried in a stove, which is an invariable ad-

LADLE FOR SMALL CASTINGS.

junct of a foundry, and of which there will be occasion to speak again. When large castings are required to be made, the size of all the appliances for conveying the metal from the furnace must be increased proportionately; and it often happens that, where the capacity of a furnace is insufficient to supply all the iron at one discharge, a ladle containing fifteen or twenty tons of melted iron is first filled and covered over with a layer of sand, and kept waiting until more iron has been melted and ready, along with the ladle-contents, to be poured into the mould.

Among the multifarious operations of the iron trade, there is none that is more beautiful than the production of a large casting; and, as the process is carried on in every foundry in the kingdom, it would be quite worth the while of our readers to witness it for themselves.

COTTON.—III.

THE SPINNING-JENNY—ARKWRIGHT'S WATER SPINNING-FRAME—TROUBLES OF AN INVENTOR.

By DAVID BREMNER, Author of "The Industries of Scotland."

IN the year 1764, just when Lewis Paul's spinning machine was being finally put aside, James Hargreaves, a Blackburn weaver, hit upon a plan whereby a number of rovings might be simultaneously and expeditiously converted into yarn. While seated in his house one day, a spinning-wheel in operation was accidentally overturned, and observing that the momentum of the wheel caused it still to revolve, he seized the roving and fed it on to the spindle, which was now in a perpendicular position. As he did so, it occurred to him that if a number of wheels were placed in the same position, and some means devised for holding the rovings of all, and drawing them out simultaneously, a saving of labour would be effected. He applied himself to giving practical shape to his idea, working in strict privacy, because he knew that any person who might propose to provide a mechanical substitute for hand labour would certainly be looked upon as an enemy of the working class. He was heavily handicapped in the task he undertook, for he had a wife and seven children depending on his efforts with his loom, so that only spare hours could be devoted to the construction of his spinning machine. In the course of two or three years the machine was completed, and, for some time before its existence became known to the outside world, was employed in producing weft for Hargreaves' own loom. Such was the origin of the spinning-jenny, the pioneer of one of the finest systems of machinery ever devised by human ingenuity.

Like most of his class, Hargreaves was a poor man, and the outlay he had incurred in connection with the production of his machine pinched him to such an extent that, in order to obtain relief, he mounted and sold several sets of the apparatus before he had secured a patent. This, as we shall see, proved disastrous to him. But prior to the misfortune which overtook him on this account, he had to encounter another. A member of his family boasted to some of the neighbours as to the possession of means whereby yarn might be produced at a rate far exceeding the capacity of the ordinary spinning-wheel. This excited both curiosity and indignation, and the spinsters of the neighbourhood besieged and forcibly entered Hargreaves' house, and without waiting to examine the machine which they found there, smashed it to pieces. In addition to this, the poor inventor's life was threatened if he dared attempt to construct another machine. Having faith in the capabilities of the spinning-jenny, he sought a fresh field for turning it to account. Accordingly, in 1768, he removed to Nottingham, and, in conjunction with a joiner named Thomas James, erected a small spinning-mill, in which he demonstrated the complete practicability of his invention. He obtained a patent in 1770 for his machine, which he thus described in the specification:—"A method of making a wheel or engine of an entire new construction, and never before made use of, in order for spinning, drawing, and twisting of cotton, and to be managed by one person only, and that the wheel or engine will spin,

draw, and twist sixteen or more threads at one time, by a turn or motion of one hand and a draw of the other."

The jenny consisted of an oblong frame, seven or eight feet in length, across one end of which a series of spindles—eight in number in the original machine, but afterwards increased to eighty—were arranged perpendicularly, so as to be driven at a high speed, by cords passed round them from a rotating cylinder. In front of these spindles was a frame containing a corresponding number of bobbins, filled with roving produced on the hand wheel. It must be remembered that the jenny did not make the yarn direct from the carding, but that it only performed the second and more important operation of hand spinning. Resting on the upper longitudinal beams of the frame, and extending from one to the other, was a carriage of light construction. The workman began operations by passing the ends of the rovings through a series of apertures in the carriage, and attaching them to the spindles. By turning a wheel, the spindles were set in motion, and simultaneously the operative drew backward the carriage and thus caused the desired elongation of the rovings. The carriage was then returned, and as it moved forward the length of yarn spun was wound on the spindle. A fresh piece of each roving was then let out, the drawing and twisting operation repeated, and so on. The equal arrangement of the yarn on the spindles was secured by means of a wire, which the spinner moved with his foot. The machine, it will be seen, was of the simplest possible character, and its construction quite within the capacity of makers of the ordinary spinning-wheels. When its merits came to be appreciated, the spinning-jenny was made in considerable numbers for the manufacturers of Lancashire, without the inventor being consulted on the matter, and as he had disposed of some of the machines before obtaining a patent, he could get no redress in the law-courts. Ultimately, the manufacturers, feeling that an injustice was being done to a man who deserved well of them, raised a fund of £3,000, and offered it to Hargreaves as a recompense for the invention. He demanded a larger sum, but his demand was not complied with, and

Hargreaves' Spinning-Jenny.

in the end he got nothing. It was a grievous disappointment for Hargreaves to see people all through the manufacturing districts enriching themselves by means of his invention, while he was left in comparative poverty to struggle on with the small factory in Nottingham, which a want of capital prevented him from extending. He died in 1778.

A great impetus was given to the cotton manufacture by the introduction of the spinning-jenny. Every weaver who could afford it bought one, and thus put an end to his troubles in procuring a constant supply of yarn. Improvements had been made in the apparatus for carding the wool, and the fly-shuttle, which was invented by John Kay, in 1738, but rejected as "a dangerous innovation for saving labour," was brought into operation; and altogether matters were in trim for the advent of the great mechanician the story of whose life and services we shall now relate.

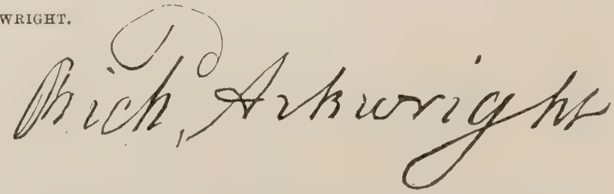
Richard Arkwright was born at Preston, in the year 1832. His parents were in a humble position of life, and, like many persons so situated, were the progenitors of a very numerous family, Richard being the youngest of thirteen children. The educational advantages now enjoyed by the poorest children in the land were unknown in those days; and, as a consequence, the future benefactor of mankind, together with his brothers and sisters, received but a very scanty amount of instruction. His childhood passed in circumstances most disadvantageous to the development of any latent genius with which he might have been endowed; nor was there much scope for its manifestation in the trade that he was set to learn. On arriving at an age suitable for entering on a term of apprenticeship, he was indentured to a local barber, to acquire the art and mystery of hair dressing and wig making. He proved himself an expert workman, and in course of time developed a fondness for mechanics. At the age of twenty-eight, he had by his thrift accumulated enough money to warrant his embarking in business on his own account. He had acquired high skill in the art of dyeing hair—an important department of the barber's occupation in those days; and to that he devoted himself, as well as to the business of a hair merchant. The latter branch made it necessary for him to travel about a great deal, and during his peregrinations he gratified his taste for mechanics by inspecting whatever machines were accessible to him. At the same time, he became acquainted with the requirements of the cotton manufacturer, and the attempts that had been made to meet them. Like many young men of similar tastes, he devoted some of his time to attempting to discover "perpetual motion," being stimulated thereto by the prevailing belief that the discoverer would receive a reward of £10,000 from the Government. In course of time, the question of the possibility of devising a machine that would convert cotton-wool into yarn without the intervention of human fingers took possession of his mind. Having matured his plans, he took into his confidence an ingenious clock-maker, named Kay, who made for him a model roller spinning machine embodying his ideas on the subject. From this model a full-sized machine was subsequently constructed, and worked so satisfactorily that Arkwright resolved at once to take steps for turning his invention to account. Proceeding to Preston, his native place, he revealed his plans to Mr. John Smalley, a publican, who readily consented to assist him in the matter, and began by securing a room attached to the Free Grammar School, as a place in which to experiment with and perfect the machine. So convinced was Mr. Smalley of the practicability of the invention, that he ultimately entered into partnership with Arkwright. But Lancashire was not at that time a favourable field for the exhibition of machines designed to supersede hand labour; and fearing that they might excite the violence of the hand spinners, as Hargreaves had done by the production of the spinning-jenny, the inventor and his friend followed Hargreaves' example, and removed to Nottingham, where they expected to find a ready and safe market among the stocking manufacturers for such yarns as they had proved the new spinning machine could produce. With the aid of a local banking firm, they established a factory on a small scale, and applied themselves to the spinning of hosiery yarns. In July, 1769, Arkwright obtained a patent for his spinning-frame. His specification stated that he had, "by great study and long application, invented a new piece of machinery, never before found out, practised, or used, for the making of weft or yarn from cotton, flax, and wool; which would be of great utility to a great many manufacturers, as well as to his Majesty's subjects in general, by employing a great number of poor people in working the said machinery, and by making the said weft or yarn much superior in quality to any heretofore manufactured or made." At that time, Messrs. Need and Strutt were among the leading hosiery manufacturers in Nottingham, and they from the first took considerable interest in Arkwright's invention. Mr. Strutt was an eminent

mechanician, and was thus capable of forming a sound opinion upon the prospects of machine spinning. In the year 1770, Arkwright and his partner were joined by Messrs. Need and Strutt, and plans were prepared for the erection of a spinning factory at Cromford, in Derbyshire, where the waters of the Derwent were available for driving the machinery. This was the first water spinning-mill ever erected, and the parent of that great factory system which has contributed so much to the fame of England in the arts of peace. The fact that the machines were moved by water power led to their being called water frame-spinning machines, and the yarn produced was known as water twist. The drawing of the first machine made, which is attached to Arkwright's specification, shows how carefully all the requirements had been thought out. Subsequently, modifications were made in the adjustment of the details of the mechanism, but the general principle of it is retained to this day in the best throstle spinning machines. As yet, the hand wheel was the only means that existed for twisting the soft cardings into rovings; both Hargreaves' and Arkwright's machines being adapted only to drawing the roving out to the desired degree of fineness, and twisting it into yarn. The great difference between the jenny and the water frame was that the former was a hand machine working intermittently, and producing a soft yarn suitable only for weft, while the latter was driven by water, and produced, at a continuous and greatly increased rate, a fine hard yarn, suitable for warp or hosiery purposes.

Arkwright's original water frame was constructed to deal with only four threads at a time. It consisted of an upright framing of wood, in the upper rear part of which the bobbins of roving were placed, and led thence to the drawing rollers, which occupied the front. The rollers, which constituted the chief feature of the machine, were about an inch in diameter, and were arranged in pairs one above the other, presenting an end view like this . When the machine was set in motion these rollers revolved, and drew the roving from the bobbins. In passing through the rollers the roving was attenuated to the required degree by a very ingenious arrangement. The first pair of rollers merely acted the part of feeders; but the second, having a quicker motion, elongated the roving to a proportionate extent; the third pair, moving faster than the second, continued the operation; and the fourth pair completed it. The action of the rollers on the roving was precisely similar in effect to that of the fingers of the hand spinner, and to the drawing to which the roving was subjected in the spinning-jenny. In order that the rollers should grip the roving with sufficient firmness, the upper ones were covered with leather, while the lower were fluted, and the upper one of each pair was pressed against the lower by adjustible weights. On emerging from the rollers, the threads were led on to a series of bobbins furnished with flyers, similar to those of the hand spinning-wheel. The spindles on which the bobbins were placed were driven at a high speed by a belt, and by a simultaneous operation imparted the necessary twist to the yarn and wound it on the bobbins. Encouraged by the success of his spinning-frame, Arkwright applied himself to devising machines for performing the other operations necessary in the production of yarn; and worked so rapidly that by the year 1775 he took out a patent for a complete system of preparing and spinning machines. Instead of being regarded as a benefactor of his country, however, Arkwright found himself at this time, and for years afterwards, an object of enmity to both manufacturers and operatives. Mr. Baines, in his "History of the Cotton Manufacture," thus describes the feeling that prevailed: "This period of high intellectual excitement and successful effort would have been contemplated with more pleasure if there had not at the same time been displayed the workings of an insatiable cupidity and sordid jealousy, which remorselessly snatched from genius the fruit of its creations, and even proscribed the men to whom the manufacturer was most deeply indebted. Ignorance on the one hand, and cupidity on the other, combined to rob inventors of their reward. Arkwright, though the most successful of his class, had to encounter the animosity of his fellow-manufacturers in various forms. Those in Lancashire refused to buy his yarns, though superior to all others, and actually combined to discountenance a new branch of their own manufacture because he was the first to introduce it." So strong was this opposition, that it was not till five years after he had obtained his first patent, and over £12,000 had been expended in buildings and machinery, that any profit accrued to himself and his partners. It appears that the Lancashire manufacturers had got the notion that Arkwright was not the author of the machines which he had patented; that he had stolen the inventions of others, and after slight modifications claimed them as his own, and by his patent prohibited others from using them without making terms with him.

Every means were taken to thwart his enterprise. His best servants were bribed away and encouraged to divulge the principles of his machines; and in various places pirated copies of his mechanism were set up and worked in secret. At this time of day it is difficult to understand the intense feeling of opposition that prevailed against one of the chief founders of our great cotton industry. It was only natural that Arkwright should seek to secure the fruits of years of anxious thought and labour; and he repeatedly sought the protection of the law for his patent rights. The Lancashire spinners formed an association to defend all those against whom Arkwright might proceed for the recovery of damages for infringement of his patents, and several keen legal contests took place. Finding that they could not dispose of their yarns to the manufacturers of cloth, Arkwright and his partners addressed themselves to converting it into stockings,

Portrait and Autograph of Sir R. Arkwright.



and this branch of business turned out a success. As already mentioned, the so-called cotton cloths made in England up till this time consisted of linen warp and cotton woof. It occurred to Arkwright that the strong yarn made by his machines might be used as warp, and experiment demonstrated that this was so. Accordingly, the firm now applied themselves to the manufacture of calicoes, for which they at once obtained a ready demand. Fortune now seemed to smile upon the enterprising inventor; but suddenly a new obstacle was placed in his path. The Excise officers had stepped in and demanded, in addition to the usual duty of threepence per yard, a like sum on the ground that the cloth, though manufactured in England,

was really Indian calico! The Commissioners of Excise were appealed to in vain; and it actually became necessary for Arkwright and his partners to go to Parliament and ask relief in the form of a special enactment freeing home-made calicoes from the prohibitive tax, and also to obtain permission to print the home-made cloth. The Lancashire manufacturers offered strong opposition to the passing of the Bill, and their conduct is thus commented upon by Mr. Baines: "The prohibition of English-made calicoes was so utterly without an object, that its being prayed for by the cotton manufacturers of this country is one of the most signal instances on record of the blinding effects of commercial jealousy." In the year 1774 the relief asked for was granted by an Act of Parliament, which sanctioned the new manufacture, and declared that the use and wear of printed, &c., stuffs, wholly made of cotton and manufactured in Great Britain, ought to be allowed, "under proper regulations;" that the duty on calicoes made in Great Britain should not exceed threepence per yard square, and that every piece of cloth should be stamped at each end by an Excise officer with the words "British Manufactory." Persons who sold the cloth without being stamped were made liable to a fine of £50 for each piece, besides forfeiture; and the counterfeiting of the stamp was made a capital offence.

MODEL ESTABLISHMENTS.—II.

THE ROYAL ARMY CLOTHING DEPÔT, PIMLICO.

By Robert Smiles.

An idea exists more or less extensively in some minds that national establishments are characterised by jobbery, peculation, dawdling, red tape, waste, and circumlocution. The idea may be correct as applied to some public departments, but not as referring to such Government manufacturing concerns as the Small Arms Factory at Enfield, or the Ordnance and Ammunition Manufactories in Woolwich Arsenal; and it certainly does not attach to the Military Clothing Factory, Pimlico—the largest establishment of its kind, probably, in the world. In this great concern the checks upon jobbery, peculation, and dawdling are perfect; there is no circumlocution, and only so much of routine as is absolutely necessary to secure efficiency and economy. In construction and arrangement of buildings, sanitary, engineering, and mechanical expedients and appliances, and in administration throughout, this great factory is entitled to take front rank as a "model establishment."

The origin of the Pimlico Army Clothing Depôt dates from 1855, the period of the Crimean war. Prior to that time, army clothing was provided for the non-commissioned officers and men of their regiments by the colonels commanding, out of the proceeds of parliamentary votes, that were apportioned *pro rata* by the Secretary for War among the commanding officers. The clothing was obtained from contractors, and the system was eminently unsatisfactory in many respects. *Punch* gave pointed expression to this state of affairs in his cartoon representing two ragged soldiers in the trenches, between whom the remarks were exchanged —"Bill (*loquitur*): Jack, they're goin' to give us a medal."—"Humph!" replies Jack, "I'd rather see first a coat to hang it on." The wretched condition of our men at the siege of Sebastopol led to inquiry into the state of the Army Clothing Department. The soldier's coat of that time was little better than that of earlier days; instead of bright scarlet it was a brick-dust colour, and in texture was of yarn, "three threads to the pound, and every pound an armful." The clothes intended to last for twelve months were, on foreign service, reduced to tatters in a few weeks. No stores existed from which to replace the rags, and reclothe our naked soldiers. Months elapsed before fresh supplies could be sent out. Complaints were numerous, need was urgent, and the Secretary for War resolved to purchase good cloth direct from the manufacturers, and employ the widows and orphans of the soldiers who had fallen, to make it up into stout and durable garments. To insure economy in the proposed factory, it was arranged that a part of the clothing should continue to be made by contractors, for periodical comparison between the two systems of supply, as touching price, quality, material, workmanship, and durability. The advice of large wholesale manufacturers was taken, as to arrangements and working, form of accounts to be kept, and other particulars. The undertaking had thus the advantage of the assistance, and in part the guidance, of practical

men of large experience. The important duty of conducting this extensive and entirely novel manufacturing establishment has since its formation devolved upon Mr. Ramsay, the Director of Clothing, assisted by Mr. Fellowes, the Assistant-Director, Colonel Hudson superintending the factory, and Mr. Quinlan the store-keeper.

The Army Clothing Depôt forms a branch of the department of the Surveyor-General of the Ordnance. Up to the year 1870, the duties connected with the clothing of the army were performed by various branches of the War Office, in Pall Mall, while the purely executive work was done at the Army Clothing Depôt. These duties are now concentrated at the Army Clothing Depôt, under the Director of Clothing, who, by the Secretary of State's instructions, is the responsible officer on all matters relating to clothing, whether administrative or executive. The interests of the soldier are carefully protected, as the following arrangements, adopted for that very purpose, will show:—(1) The Commander-in-Chief, subject to the approval of the Secretary of State, selects the standard pattern of every article. (2) Whenever supplies are sent to a regiment, a sample is sealed by the Adjutant-General; and upon receipt of the clothing at the regiment, a board of officers examine the articles to see that they correspond with the sealed sample, and any complaints are immediately reported to the Adjutant-General. (3) Annual reports from every regiment are made to the Adjutant-General, showing how the clothing has worn during the past year, and pointing out any defects in quality or make.

The Depôt is a homogeneous establishment, in four distinct departments:—(1) The Central, in which all arrangements for clothing the army are carried out; (2) Inspection, in which all materials are examined, and manufactured articles compared with approved samples and standard patterns; (3) the Storekeeper's Department, where all supplies are received, and kept till required for issue; and (4) the Factory, where head-dresses and clothing of various descriptions are manufactured; the whole being under the personal supervision of the Director. Exclusive of outlying buildings, the Military Clothing Depôt consists of two ranges of three floors, each 600 feet long, that reach from Grosvenor Road, on the Thames Embankment, northwards to Chichester Street. Each range has in the centre an entrance portico, and is flanked by gates and porters' lodges, with constables and timekeepers on duty. One set of gates is for the Storekeeper's Department; the other for the Inspection and Factory Departments. The front portions of the two ranges of buildings referred to are occupied as the Officers' Rooms and Clerks' Offices. The buildings are connected by a covered bridge over the roadway.

The magnitude of the business necessitates excellent methods to secure honesty and efficiency. The orders received at the factory are sometimes large and urgent. As an example of the work that can be done by this establishment in moments of emergency we may instance the case of the Ashantee war. That expedition was very quickly determined on, and the equipment of the troops to fight in an African climate was different altogether from that used in ordinary campaigns. The intense heat and moisture of the West African coast required a dress that was light and bearable on the march, and at the same time sufficiently warm during the damp and foggy nights to protect the men from the chill which is the sure forerunner of fever. A head-dress had to be invented which should protect the wearer from sunstroke, and at the same time be as light as cork. The Elcho tweed, a light, tough, elastic material, was selected by Sir Garnet Wolseley for the clothing, and a cork helmet was approved for the head-dress. The supply for the entire force was made in a few days, and the expedition was sent off in an equipment which was admitted, on the termination of the war, to have been admirably adapted for the purpose. Under the old system of putting out tenders for clothing, and going through the red-tape process of supply, the war would have been at an end before the first garment reached the troops. In a general way, the quantity of clothing to be made during the course of the year having been determined, a division is made into weekly portions, with a view to the equable employment of the work-people, so that there may not be slackness at one time and a spurt at another. The period at which each issue of clothing has to be finished and sent off, whether to Hong Kong, the Mauritius, Cape of Good Hope, Halifax, or Bermuda, has to be arranged, as well as the time for delivery to regiments on home service. The storekeeper, requiring, say 5,000 tunics, of given measurements, sends a requisition to the factory. The foreman cutter enters on the back of the paper the quantity of cloth required. The document is returned, to reappear with the materials, which are checked off by the receiving clerk. The date, number, and all particulars, are then posted in the foreman cutter's record, in which is shown the hour at which the material

is received, the time at which it is cut, the examiner to whom it is sent down, and the date on which the order is finished and handed over to the storekeeper for despatch. From this record a few seconds suffice to show the state of progress of any order, and a few minutes to ascertain in whose hands any particular garment is at the moment, and when the last garment of the order will be completed. The books are so arranged as to trace everything that comes into the building from one person to another, through each stage of its manufacture, and to arrive at the person responsible for it. In the event of anything being lost, the last person who signed for its receipt has to make it good. The checks throughout are perfect.

The grand feature of the establishment is the great work room, 260 feet long by 40 feet wide, and 70 feet in height, of which we give an engraving. The inspection department occupies an extension of this block of buildings to the north. This room is in a quadrangle, with a roof double glazed to prevent drip to the interior. Although the roof has a straight sweep on each side, it appears to be semicircular in form, from the elegant iron principals upon which it is supported; these, in turn, rest upon graceful iron columns, rising from the ground floor. On each side of this quadrangle are three floors providing six work rooms, each 260 feet long by 25 feet wide, and 16 feet high. The two upper floors have windows to the interior; the first floor has galleries running along each side of the central space, and wide galleries are carried on the level of both floors across each end. From either of these the *coup d'œil* is remarkably striking. The single ground floor of the quadrangle is furnished with fifty-eight tables, that have passages down the centre, and at each end. Nine seamstresses are employed at each of these tables, including one machinist; the eight other workwomen "baste" and sew by hand. The machinist is a rather important person, upon whom the other workers are, to a certain extent, dependent, and a part of the order and discipline of the establishment—which, by the way, seem to be perfect—is, that the machinists should wear scarlet jackets, unless they are in mourning, when they are granted a dispensation. The scarlet jackets of the machinists, the scarlet garments in progress, and the parti-coloured dresses of the workers, with the hum and whir of activity, combine to make the scene one of the most picturesque and interesting character. From a standpoint upon one of the cross galleries views are also had of the extensive work rooms on each side. The noble, light, and spacious work hall is admirably ventilated by louvres under the eaves of the roof. Two of the adjoining ranges are sewing rooms, in which the same kind of work is being carried on as in the great hall below. Three of the other side rooms are for cutting out, and another is a viewer's or examiner's giving-out room. There are 188 sewing machines, adapted for heavy tailoring work, employed in the building. These are worked by steam power, which greatly abates the strain upon the worker. All materials for army clothing and equipment, including boots, saddles, spurs, &c., pass through the Depôt, where they are tested by sealed patterns. The principal articles of clothing produced at Pimlico, bewildering in their variety, include tunics, trousers, and great coats, for Horse and Foot Artillery, Royal Engineers, Foot Guards, Line Regiments, including Highlanders, Rifles, Zouaves of West India Regiments, Army Service and Hospital Corps, Pensioners, Militia of all kinds, &c. The varieties embrace clothing for tropical, as well as for home service. In every regiment the staff sergeants, sergeants, band, drummers, and privates, wear different dresses. Notwithstanding all this variety, when orders come to the factory for eleven or twelve thousand of these garments in a week, not a coat may be cut for any rank in excess of the exact number required, and every garment must be of the exact measurement asked for. The materials used include scarlet, blue, and rifle-green cloth, and tartans, of various qualities; of cloth, four for tunics, six for trousers, and two for great-coats. Large quantities of tweed, flannel, linings, sewings, buttons, badges, braid, leather, &c., are also used. All these materials are thoroughly tested and examined on receipt in the inspection department by the standard pattern. The make of garments is about 11,000 per week; in some years a turnout of over 600,000 has been reached. The cost of production of tunics ranges from 15s. for the tunic of a private in the line to £36 for the state coat of a Royal Trumpeter. There are about 200 different varieties of tunic. For the artillery there are thirty-eight sizes made, and for the line twenty sizes, the basis being height, and girths round the chest and waist. The principal non-commissioned officers have their clothes made to measure; privates of all sizes are well fitted by the method adopted at Pimlico. Clothing for the cavalry is not put together here, nor are the belted plaids in which the Highland regiments

delight. The cavalry corps have their own tailors, who make the clothes of the regiment; the Highlanders are fastidious as to the plait of the kilt, so these regiments make up either the whole or part of these garments; but all cloth and tartan must be passed at the Depôt before it can be issued for use. Tartan "trews" of eight patterns are made in the factory, a troublesome duty, from the "fash" of making the stripes meet at the seam. In the Life Guards the commanding officers find the clothing of their regiments.

In making up clothing, cutting out is the first process. The Superintendent of the Pimlico factory, after careful observation, concluded that more might be got out of a bale of cloth than had hitherto been done, and he contrived, with the help of the master cutter, to reduce the quantity required for a tunic from 1 yard 12 inches to 1 yard 7¾ inches: thus getting eight tunics out of the cloth that had formerly been required for seven, and still leaving sufficient margin for stout seams. In the master cutter's room these 44 inches of cloth are carefully mapped out with the paper patterns; there are 15 pieces in every tunic, exclusive of linings, trimmings, &c. The marked length is laid upon the top of 29 thicknesses of cloth of exactly the same length. The fibres make the layers adhere without any particular pressure, and the cutter attacks the pile with an endless band-knife, on a frame attached to an iron table. The knife revolves upon two wheels, one above the other under the table, through which it passes by narrow slits. The operator moves the 30 plies of cloth to the knife, and takes off in succession 30 of each of the pieces required for a tunic in less time than it takes to describe the process; the curves and points on the block of cloth being as clean and sharp as they could have been if cut from a solid cheese. In another place experienced cutters use the ordinary shears upon the garments of the measured men. The cuttings of all kinds, few of them bigger than one's thumb-nail, mere shreds and patches, are sold for more than £8,500 per annum; such is the magnitude of the business. Linings, canvas, and other materials, are cut out in the same way, up to 60 thicknesses at once. In a room with specially designed machinery these band-knives are ground as they require it; they are also sharpened by the workman at intervals, while they are in motion, by a process that makes the sparks fly "like chaff from a threshing-floor." There are ten of these steam-driven cutting machines in the factory; each machine is attended by two men, a third chalks the diagrams on the cloth, and four others roll up the cut-out pieces for distribution under the direction of the foremen viewers.

The mechanical contrivances for pressing the seams are very ingenious and effective. The "goose," which is weighted, is heated by a gas jet, with a pipe attached to carry off the heated air. It is suspended over the ironing-board. The iron is applied to the seam by the pressure of a treadle, which raises the board and also allows the iron to descend. The slung iron, working on universal joints, is easily moved by hand, and a pressure of about 200 lb. is thus obtained by the action of the foot, with very slight exertion. The temperature of the well-ventilated ironing galleries, in which a large number of women are employed, is no higher than that of any other part of the factory.

Once upon a time the buttons on soldiers' coats were of pewter, with fixed shanks that were constantly breaking off. Every regiment had its own button and device, in the number of the regiment. There were about 250 patterns of button; the dies got broken, and the system caused much trouble, delay, and expense. All this has been changed by getting the royal arms adopted as the line button, which is of brass, with a sliding shank. There are now only five patterns of button. Regiments are, however, tenacious of their distinctive badges, worn on the collar, and these, as well as buttons, Birmingham furnishes at a low price, as it can do muskets for the Caffres, or idols for the Chinese. Regimental badges are very numerous and varied: roses, thistles, shamrocks, lions, tigers, boars, sphinxes, castles, &c. These, and all other sealed standard patterns, in triplicate, are kept in the pattern room, in which are stored more than 10,000 varieties of articles, including glazed hats for dockyard men and the Thames Police, clothing for Post Office employés, and the police forces of London and Japan, for lunatics in military asylums, as well as head-gear and coats from drummer boys in line regiments up to State Trumpeters in the Life Guards. No one may, on any pretext, take the sealed standard pattern out of the room; the duplicate may be lent, with the specification, to an intending contractor; the triplicate is used for testing the finished goods.

The Head-dress Department is interesting. The cork helmets are of 20 sizes, the difference being ¼ inch between each. They are made on a cast-iron block. On this a layer of stout calico is fixed,

Central Hall of the Royal Army Clothing Depôt, Pimlico.

then coated with melted caoutchouc; a sheathing of cork $\frac{1}{16}$th of an inch thick follows; again cement, and another layer of cork of the same thickness as the first. Upon the cork the cloth cover is laid, also with cement, and the helmet is ready, having been dried in a stove at intervals, for the finisher, and then for the ventilating spike, the star and regimental number in front, the binding, chin-strap, &c. In addition to the varieties of helmets for home service and in the tropics, there are 23 varieties of forage caps produced at the factory.

Among other improvements in soldiers' clothing may be noticed the abolition of the unbending leather stock, rigid as sheet-iron. All that is left for it now is a tab of flexible enamelled leather, 3 inches by $1\frac{1}{2}$ inch, that connects the collar in front. These tabs are punched out a dozen thicknesses at a stroke of the machine.

The management undertake the duty of inspecting contract and other clothing for various public departments: such as Irish Constabulary, the General Post Office, the Metropolitan Police, &c. I noticed 14 experts engaged in the inspection of boots for the police, made in prisons, and by contractors; 500,000 pairs a year are thus inspected. During the American war the "rejections" were readily bought at good prices, by agents from the United States. Under inspection I also observed a quantity of excellent well-made police clothing from Dartmoor, including, perhaps, some work the "Claimant" may have executed.

Reverting to the manufacturing department: there are 11 viewers who give out the work, superintend its execution, and receive it on completion; each of these has 140 female workers under his direction. About 200 women have work out, the total number of females employed being over 1,700. About 300 men and boys are also employed in the works. A number of the men are soldiers, in training to become regimental tailors. Almost all the work is paid for by the piece, the prices being calculated with such exactitude that the workers, who are supplied with tickets before pay-day, know exactly what they are to receive; and the weekly payment of about £1,500 is quickly distributed in what may be called a "march past." The ticket is presented with one hand, and the wages received with the other. About half an hour suffices to pay more than 1,500 women.

The earnings of the women vary considerably; not a few earn from 20s. to 25s. per week, and even more, if clever, and upon well-paid work; 4s. and 4s. 6d. per day are not unusual amounts. As in "secondary schools," so it is in the Pimlico factory; candidates must undergo a preliminary examination. Essential qualifications are—good character and aptitude for needlework. The "examiners" are, the Matron, the Foreman Cutter, the Foreman Viewer, and the Instructor. On passing examination, candidates are placed in a trial division for probation, before being entered on the books for regular employment. The earnings of the seamstresses depend, of course, upon their quickness and industry. Of two women engaged on the same kind of work, one will earn with apparent ease a sovereign in the same time that it takes her neighbour to earn half the amount. Of the applicants for employment, less than one per cent. are found suitable, a large proportion of them being servants out of place, artificial flower makers, and young women who have not been brought up to any kind of useful work. On the other hand, new hands are occasionally taken on who can scarcely make a button-hole at starting, but who from singular aptitude speedily master the difficulties of tunics, and make up the garments *secundum artem;* others never get beyond the first rudiments of the work.

The factory is served by a steam engine of 25 horse-power nominal, which drives the sewing machines, works the seven lifts, the cutters' knives, and other appliances requiring steam power. Shafting is fixed where needed. For tool-making, sewing machines repairing, &c., an engineers' shop is provided. It is furnished with planing, shaping, slotting, and drilling machines, steam and treadle lathes, &c. Some highly ingenious tools and appliances, such as the ironing arrangements, and the button-hole machine, are produced in the factory.

One of the evidences of kindly concern for the comfort of the work-people demands mention. An attempt was made to provide dinners at cost price for the workers. The numbers of diners fluctuated very much, and the attempt was abandoned until some improved arrangements could be carried out. The provision of coffee in the morning, and tea in the afternoon, is a highly-appreciated boon. Those who desire to take either give timely notice, and are served with numbered tickets. As the man passes round to ascertain how many have to be provided for, he exchanges tickets for pennies, as required. The meal-room has accommodation at eight tables for 136 sitters. When tea is ready a whistle is blown *once* from the end gallery, and the holders of No. 1 tickets take their places. When these have been served, and the cups and saucers

are cleaned, *two* blows of the whistle bring up the holders of No. 2 tickets, and so on, until all have been served. The charge for a pint of good tea is one penny, and for a round of bread and butter, or of seed or plum cake, the same. There is a slight loss on the bread and cake, which are cut with a gauged machine, from loaves of uniform size. Upon the tea there is a profit, from which, in 1877 for instance, 27 invalided workers were sent to the sea-side for three weeks, and 18 more to Brompton Hospital. Among a number of others £44 was lent, free of interest, from the profit fund, which seldom loses by defaulters. A balance of £120 to credit, after meeting these and numerous other disbursements, was left in the bank. The consumption of tea is about 1,300 pints per day. The tea, sugar, and milk, of the best quality, are bought wholesale, upon the most favourable terms. The furnace at which the tea is made serves for the warming of the factory. The refreshment department is managed by a committee of three members elected by the work-people. Under their direction, from day to day, the tea, coffee, sugar, milk, bread, and cake are given out in accordance with the requisitions and receipts of the collector. The tea and coffee service is eagerly taken advantage of by the men, as well as the women, employed in the factory, who prize the products of the tea-room as luxuries much to be preferred to beer. In addition to these material benefits, it should be mentioned that Miss Connolly, whose name is a household word among the benevolent, has placed other advantages within the reach of the Pimlico workers, in establishing a savings bank, a sick fund, and a burial club for the women. Miss Connolly and her friends attend every Saturday to receive contributions and conduct the business of these associations. Another benevolent lady, who devotes her life to warm-hearted practical well-doing, has provided a large room for the evening instruction and entertainment of the women. She and her friends kindly meet the seamstresses, who flock gladly, bringing their work with them, to the place of resort; and while the one set of women read, sing, and play for the gratification of the humbler members of the sisterhood, they happily "stitch, stitch, stitch," but *not* "in poverty, hunger, and dirt." In summer-time, this good angel and her companions take the women into the country for a day's delight amid the verdant and floral beauties of nature.

The establishment of the clothing factory has been of great advantage to the public service in reducing the price, while improving the quality, of military clothing. It has dealt a heavy blow to slop contract work, and greatly abated the miseries incident to the "sweating" system, under which the poor needlewomen are the principal sufferers. In the Government factory the condition of the operatives is greatly ameliorated. They work in large, well-lighted, warmed, and ventilated rooms, have good wages, permanent employment, and are happy, healthy, and contented. The testimony of those most competent to express an opinion concerning the character of the establishment is strong and conclusive in its favour.

In order to guard as much as possible against the dissemination of small-pox and other contagious disorders that might be conveyed to the troops by means of clothing made in infected houses, a Deputy Inspector-General of the Army Medical Department, with a Dispenser of Medicines, is attached to the clothing establishment. They see the operatives daily, and examine into all cases of ill health. They have a list of the work-people and of their abodes, and for each person employed, a certificate is provided on which is recorded as follows:—"I hereby certify that in the house in which A B resides, there is no small-pox or other contagious disorder capable of being conveyed to others by the clothing intrusted to A B to make for the Government factory." This certificate is duly signed by a medical practitioner, and a register is kept in which the residences of the operatives and the dates of the visits are duly recorded.

This is the only establishment, public or private, in which a medical officer and a dispenser devote their whole time and attention to the health of the operatives. As far as can be ascertained, no one, from the most fashionable West-End tailor to the smallest army contractor, incurs this expense.

Minutely detailed accounts of the stock and operations at the factory are prepared annually, and are open to the criticism of Parliament and the public.

To the Director and Superintendent I owe my grateful acknowledgments for the facilities they kindly afforded me in making my notes.

FOREIGN RIVALRIES.—II.

COAL AND OTHER MINERALS.

By H. R. Fox Bourne.

GREATLY favoured in its possession of mineral wealth, England has profited immensely by the skill and energy of its people in making good use of the treasures at their hand. Its trade in tin has lasted for more than two thousand years, and, though the value of its copper, lead, and iron was not so early understood, the comparatively recent development of British industry in connection with these metals, and especially with iron, has been one of the marvels of the world. To feed its metal and other manufactures, and to meet the requirements growing out of them, moreover, the stores of fuel with which our country is also richly endowed, have been drawn upon and utilised to an extent which even two or three generations ago would have been held impossible. In the first year of the present century less than 10,000,000 tons of coal were raised in the United Kingdom; in 1845 the produce was about 32,000,000 tons; in 1876 it exceeded 133,000,000 tons. About one-fifth of this quantity, or 27,000,000 tons, is consumed annually by the steam engines employed in our great manufactories; and it has been reckoned that the motive power thus generated does the yearly work of at least 7,000,000 horses, or as much as 49,000,000 strong men could accomplish! From that statement some notion may be formed of the way in which the opening up of our mineral resources has contributed to our progress as a nation.

As regards coal, indeed, it may be fairly questioned whether our resources have not been opened up too freely. In this respect coal stands apart from all other minerals and all other industrial products. Of iron, tin, lead, and copper we can hardly raise or manufacture too much, either for use at home or for exportation, provided only a remunerative price is obtained for whatever is sent into the market; but there is certainly ground for caution, if not for alarm, in the continuous growth of our coal trade. Great Britain, it is true, has a larger stock of this most important of all fuels than any other country in Europe—perhaps nearly as much as all of them put together. Its consumption is vastly in excess of that of all the rest of the world, however, and there appears to be no limit to its increase. During the season of prosperity in the iron trade which culminated in 1873, the high prices obtained for coal gave a fresh stimulus to its production, and the subsequent commercial depression, instead of lessening the supply, has only induced rival colliery proprietors to overstock the market in endeavouring to undersell one another. It is undoubtedly to the interest of our manufacturers and traders that coal should be cheap and plentiful; but if, as in this case, abundance breeds recklessness, and future prosperity is risked for immediate profit, the advantage is very short-lived. It is estimated that, by strict economy in the use of fuel, and by adoption of the best scientific arrangements at present available, even without such further improvements as inventive zeal might be expected to point out, at least half of the coal now consumed in our various manufacturing and trading operations, as well as in domestic ways, could be saved. England is not justified in thus playing the spendthrift with its mineral treasures, because those treasures appear for practical purposes to be inexhaustible. Even if the Royal Commissioners—who reported in 1871 that, at the present rate of consumption our coal mines cannot be exhausted in a thousand years—were correct in their calculations, it is evident that, the deeper we dig down, the greater will be the labour and the consequent increase of expense, however small and slow, in bringing the commodity to the surface. Who can say how soon the time may come when the advantage we now have over most foreign rivals will be lost?

Our present advantage consists in many things besides the mere fact of our possessing an unusually large store of fuel. English coal is for the most part especially suitable for the uses to which it has to be put. Much of it is found in convenient proximity to the iron in manufacturing which so large a quantity is employed, and much also is within easy reach of ports from which it can be cheaply sent abroad. More than all, in the working of our collieries, whether we consider the mechanical arrangements of our mines, or the training and vigour of our miners, we have been till lately, if we are not still, far ahead of all foreign competitors. It is only too easy to see, however, that in many, if not in all of these respects, there are dangers more or less near and grave in the way of our continued supremacy as a coal-producing nation.

It will be long before some of the richest coal fields in the world, as for instance those of the Asturias, Cordova, and Catalonia in Spain, will be made much use of, the people who own them having yet to be educated in industrial art and energy; but other countries are already boldly entering into rivalry with us. So it is with Belgium; and yet more, because the areas to be worked are so much more extensive, with Germany, which has important coal fields in Upper Silesia, Saarbrück, and Westphalia: the last, situated in the valley of the Ruhr, near its junction with the Lower Rhine, being not only the largest in area, but also now the most productive. The history of this Westphalian coal field well illustrates the nature of the foreign competition with England that is growing up in many localities. "Twenty years ago," Mr. Cliffe Leslie wrote in 1869, "the Ruhr Basin was nowhere in the industrial race: now it produces nearly half as much coal as the great northern coal field of England. Twenty years ago it had only just completed a single line of railway; now the basin is a network of branches, connecting not only the towns, but the principal manufactories and collieries, with the three main lines which traverse it. The immense increase of production is mainly attributable to the introduction of railways and the low charge of the carriage of coal. Down to 1851 the Ruhr and the Rhine were the only means of transport in districts beyond the immediate neighbourhood of the collieries, and the greater part of the coal was of an inferior kind, raised where it came to the surface by small collieries along the Ruhr. In 1851 the Cologne-Minden Railway came into use for the transport of coal, and led not only to deep-pit sinking and the discovery of seams of superior coal in other parts of the basin, but also to the establishment of iron works and other manufactories, affording a local market for the coal. To this local market, down to 1859, it was in a great manner confined. In that year the charge for railway carriage of coal for long distances was reduced to one pfenning per centner per German mile"—rather less than a farthing a ton per English mile—"and the result was immense increase of production. The railways and coal mines render each other reciprocal service. The carriage of Westphalian coal is now one of the most important branches of traffic on several of the chief Prussian lines, and the low rates at which it is carried enable it to find a distant market. The projected reduction of the rate for the transport of iron ore to the same tariff as that for coal, when carried into effect, will greatly augment the market for coal as well as for manufactured iron. Until the last few years the Ruhr Basin excelled only in the manufacture of steel, but its iron manufactures are now of the highest quality." The same process is going on in many other parts of Europe, threatening not only the coal trade of England, but much more seriously the iron trade, which is always largely dependent on the accessibility of the fuel necessary to its operations.

The greatest danger to England, however, in respect of coal, will certainly come, though, perhaps, not at once, from the United States. Not only are the North American coal fields at least ten times as extensive as those of Great Britain, but they abound in the richest varieties of coal, much of which is very easily to be got at, and in convenient proximity to the almost equally abundant stores of iron. Whereas in 1840 the output of anthracite coal was only about 1,000,000 tons, in 1875 it reached 21,000,000, the supply of bituminous and other coal in the same year being about 25,500,000 tons. Only a generation having elapsed since the American mining industries were in their infancy, their progress has been an amazing one. They have laboured under both natural and artificial difficulties. In a sparsely-peopled country, the expense of transit is necessarily great, and labour is often very costly. Both these obstacles, however, have been in great measure overcome already, and the country has flourished so much in spite of mischievous commercial legislation and the follies of unprincipled speculators, that when these have been got rid of, its industries may be expected to increase with even more startling rapidity than heretofore. Even should the United States do no more than use their own coal to feed their own manufactories and supply their own inhabitants with all such commodities as have hitherto been sent across the Atlantic from Europe, and especially from England, the effect will be considerable. But more than that must be looked for. Already our American cousins are competing successfully with us in many of the markets of the world. With their increased skill in manufacturing for themselves will come increased ability to cater cheaply for the wants of other nations. The possession of coal and iron in abundance means power to make and sell almost everything. That power will certainly be used more and more every year by the capitalists and working men of America.

In certain respects, as regards coal and other mining, England and the United States, whatever

rivalry may exist between themselves, occupy and will probably continue to occupy, nearly the same position as competitors with other nations. The American working classes are naturally of almost the same temperament as their kinsmen in this country, and exhibit substantially the same merits and demerits. The average English collier is able to do at least half as much work again in a day as a Frenchman or a Belgian, and he is also greatly superior to an ordinary German. An American is generally his equal, and often even gets through considerably more work in a given time. Both Americans and Englishmen, however, expect higher pay than Continental labourers, not only because they require more food and other necessaries of life to keep up their physical superiority, but also because many of their tastes are extravagant. In 1874, a season of high wages, Mr. Lowthian Bell, instituting a careful comparison between the English and American wage rates for mining, found that an American produced 13 cwt. of coal in an hour, for which he received 1s. 1d., while an Englishman obtained 1s. 2d. for turning out 11 cwt. in the same time, the difference being mainly caused by the greater facility with which American collieries are generally worked. On both sides of the Atlantic the rate of wages has of course been considerably reduced in later years, but now, as heretofore, the labourer on the Continent gets far lower wages than his rival either in England or in America. Though he toils for a longer period each day, the produce of his toil is far less. Whether this difference is likely to be permanent may well be doubted. Great efforts are made by many employers abroad, and especially in Belgium, to improve the condition of their workmen. No one visiting the mining establishments in the neighbourhood of Liége, for instance, can fail to be astonished—however much he may object to the excess of paternal authority, leading to something like serfdom, thus displayed—by the elaborate and benevolent zeal with which the colliers and other labourers are cared for in all domestic concerns. A spirit of independence is hardly encouraged thereby; but the physical power of the workman is increased. "The value of the English workman," says Mr. Redgrave, "still remains preeminent, although the interval between him and his competitors is not so great as it was. He has not retrograded, but they have advanced." That implies, other conditions of rivalry being stationary, that the foreigner is gaining on the Englishman; and, if it be so, the result must necessarily be unfavourable to the supremacy of English industry.

It is not necessary now to say much about the various minerals that have become great staples of British manufactures and commerce, as in future chapters we shall have to note the principal features in the competition between our own and other countries in converting them from the raw material into articles of use and ornament. We have had, indeed, to refer to iron more than once in our remarks on coal. The great value of our iron wealth, as compared with that of other nations, depends largely on the convenient proximity of the ore to the fuel needed for its manipulation as well as its extraction. Till lately, in fact, through the occurrence of clay ironstones in the coal basins of West Scotland, Staffordshire, and South Wales, both minerals were obtained from immediately adjacent, if not actually from the same pits. These stores have been to a great extent exhausted, but our country still has the advantage of possessing deeper seams of ironstone, which only began to be opened up some thirty years ago, in North Yorkshire, Lincolnshire, Northamptonshire, Oxfordshire, and Wiltshire, and which are sufficiently near to the coal fields to render their working easy and very profitable. The discovery of the Bessemer processes, again, has greatly enhanced the value of the hæmatite ores that were formerly of small account. Of the 16,841,583 tons of iron ore produced in 1876 about a third was of the first-named description, more than half of the second, and a seventh of the third. When noticing the competition between England and foreign countries in manufactured iron, we shall have some evidence of the dangerous rivalry offered to us by favoured Continental districts in consequence of their possessing iron seams nearly as readily workable as ours. It is from the United States, however, that in the more or less distant future the greatest opposition may be expected in respect of iron as well as of coal. There the distances between the two materials that have to be brought together cause heavy expense at present, but the ores are, on the whole, of unrivalled quality. "Taking all the iron ore raised in Great Britain," says Mr. Lowthian Bell, "its average percentage of iron will be a trifle under 35 per cent., whereas the produce of the mines of the United States, similarly considered, will be about 56 per cent.; which means that for each ton of iron made there is a ton less ore to be dealt with by the American ironmaster than by ourselves. This, in smelting charges, and particularly in the matter of transport, is a very important distinction." That is only the chief of

many advantages which the Americans possess over the English iron manufacturers, and of which they may be expected naturally to make great use.

In comparison with iron, the other mineral treasures of Great Britain, famous as they were in old times, are almost insignificant, and therefore the dangers offered to our national welfare are less momentous. Yet, in some cases, there is ground enough for alarm. Whereas a hundred years ago the annual yield of tin from the Cornish and Devonshire mines was only about 3,000 tons, the quantity was 13,688 tons in 1876. There has been a steady decrease, however, for several years past in the English supply, and yet more in the price obtained for it, the produce of the East Indian islands and of Australia being now brought over so freely as to cripple home enterprise. What is gain to the manufacturers is thus a serious injury to the mining classes. The lead mines, which stand next to tin in order of value, are hardly at all affected by foreign competition; but the prospects of the copper mines are yet more gloomy. The yield of copper ore in 1869 was 129,953 tons; in 1872 it had sunk to 91,983 tons; and in 1876 it amounted to only 79,252 tons. The fluctuations in the zinc trade are considerable from year to year, but these are due chiefly to local causes. Prussia and Belgium have already, as regards this metal, inflicted upon our country nearly as much injury as can come from foreign competition.

HEMP, FLAX, AND JUTE.—IV.

THE FLAX PLANT AND ITS CULTIVATION.

By David Bremner, Author of "The Industries of Scotland."

PERSONS who have visited the North of Ireland when the flax plant was in flower, must have carried away pleasant recollections of the appearance presented by the fields. Indeed, it would be difficult to conceive anything more beautiful than the broad expanse of delicately-formed blue flowers, borne aloft on their slender stems, and undulated by the gentlest breeze. In many cases the raw materials of industry present little attraction to the eye, but here we have what may be truly described as "a thing of beauty." When the flowers give place to the seed vessels, and the fields assume a more sober hue, the plant still retains a captivating grace of form, and as it shakes its capsules in the breeze, gives out a low rustling sound, which soothes the ear like the murmur of a brook. If a stalk or two be pulled and jerked between the fingers till the woody core becomes separated from the fibre, it will be seen how strong and silk-like the latter is. This experiment will also show how firmly adhesive the fibre is to the core, and serve to explain the necessity for the operation employed in their separation on a large scale.

The botanical name of flax is *Linum usitatissimum;* in German it is *flachs;* Dutch, *vlasch;* Russian, *len;* French, *lin;* Italian and Spanish *lino.* In botanical phraseology the plant is described as follows, but persons who are not familiar with the scientific terms may form an excellent idea of its appearance from the accompanying engravings:—Flax is an annual, rising on a single stalk to the height of from 20 to 40 inches. The stem is smooth, simple, and erect, of a beautiful green colour, and when at its full height, it is crowned with a number of small bright-blue flowers, of very delicate texture and elegant form. The leaves are alternate, sessile, linearlanceolate, and smooth, and the flowers are arranged in a corymbose panicle. The sepals, or green outer leaflets of the flower, are five in number, ovate acute, slightly ciliated, and nearly equal to the capsule in length. The five petals are obscurely crenate, comparatively large, and deciduous. The stamens are alternate with the petals, and have their filaments united together near their base into a sort of ring. The ovary, or young seed vessel, is divided into five cells, surmounted by five stigmata, and the capsule or boll is roundish, but rather pointed at the apex, divided into five cells, each sub-divided into two, thus forming ten divisions, each of which contains one seed. The seeds are of an oval shape, plump, smooth, and shining, generally brown externally, but white internally, the seed coat mucilaginous, and the kernel oily and farinaceous. The stem consists of a pith and woody part, with a layer of bast fibres, covered with cuticle on the outside. When carefully cultivated for the fibre, there are only two or three seed vessels to each stalk, and few or no branches, but any there are spring from near the top of the stem. Shortly after flowering, the aspect

of the plant becomes changed, and the handsome flowers give place to the small, rough-cased globules or bolls filled with seed.

There are four varieties of the plant. One, known as *ulsee* or *tesee*, has long been grown in India for the sake of its seed, and owing to the fibre being of no consideration, the stem has, through neglect, become much branched and stunted, and coarse. It is believed, however, that were attention paid to the growth of the stems, the plant would, in course of time, assume the characteristics of the kind grown in Europe. Though the fibre is with us regarded as the most valuable product of the plant, the seed is an important article of commerce. It contains a large proportion of oil, which, when expressed, is known as linseed oil, and is applied to many purposes. After the oil has been extracted, the refuse is pressed into cakes, and is largely used as a fatting food for cattle, while the ground seed, known as linseed meal, is a well-known emollient. One bushel of East Indian seed yields from $14\frac{3}{4}$ lb. to 16 lb. of oil; of Egyptian, 15 lb.; of Sicilian, from $14\frac{1}{2}$ lb. to $15\frac{1}{2}$ lb.; of Russian, from 11 lb. to 13 lb.; and of English, Irish, or Scotch, $10\frac{3}{4}$ lb. to 12 lb. Our imports of seed, oil, and cake, are very large. In 1829, we imported only a million and a half bushels of seed; now we take six or seven times that quantity every year, at a cost of between three and four millions sterling. Of seed oil we took in 1876, 22,759 tuns, valued at £811,421, and of oil-seed cake 190,281 tons, valued at £1,768,231. The seed from which flax is raised in Ireland and other parts of the kingdom is for the most part imported from Russia and Holland, and as on the quality of the seed the success of the crop chiefly depends, great care is taken in its selection. As the seed, when kept long, loses its germinating powers, means are taken to insure that the seed purchased for sowing is of the previous year's growth. Riga seed is the kind generally used in Ireland, as it is best adapted to produce a fine quality of fibre from the soil of the country. American and Dutch seed find favour with some growers. An interchange is believed to be rather advantageous, for it does not suit to raise the crop from the seed saved on the same ground, except, perhaps, in an occasional year.

FLAX PLANT. (*One-fourth Nat. Size.*)

(1) Stamens and Pistils, six times nat. size; (2) Seed Vessel, nat. size; (3) Section of Seed Vessel, twice nat. size; (4) a Seed, slightly magnified.

According to Professor Hodges, of Belfast, the chemical composition of the flax plant is as follows:—

Water	56·64
Organic matters	41·97
Ash	1·39
	100·00

The stem of the plant, when dried, contains 96·89 of organic matter, and yields 3·11 of ash. The ash contains:—

Potash	20·32
Soda	2·07
Chloride of Sodium	9·27
Lime	19·88
Magnesia	4·05
Oxide of Iron	2·83
Sulphuric acid	7·13
Phosphoric acid	10·24
Carbonic acid	10·72
Silica	12·80
	99·31

Climate and soil are, of course, most important factors in the successful cultivation of the flax plant. Mr. Warden, in his admirable work on "The Linen Trade, Ancient and Modern," says, the climate most suitable for the growth of the plant is one having a regular supply of genial moisture in spring, without an excess of wet in autumn, and where the temperature is pretty equable throughout the season. A severe drought, with a hot sun, after the plant has risen two or three inches above the ground, is very detrimental to it. The delicate leaves are then unable to exclude the scorching rays from the surface of the soil, and as the roots have not had time to penetrate sufficiently deep to secure a supply of moisture, the plant droops,

turns a whitish yellow, and, if the drought continue long, it dies. Long-continued droughts are therefore a great enemy to the flax grower, and as these are less frequent in the British Islands than on the Continent, this country would appear to be more suited for its cultivation. When the plant thoroughly covers the ground, dry weather does little injury; but occasional gentle showers are requisite to stimulate its growth, from the germinating of the seed until the flax attains maturity. Alternate showers and sunshine make the most vigorous plants, and produce both quantity and quality of fibre. Short, hot summers induce too rapid a growth, and, although the quantity of fibre produced is large, the quality is never fine. In Egypt, though the plant attains great luxuriousness in the rich alluvial soil of the Nile, and efforts have been made to improve its culture and preparation, yet the fibre does not reach the degree of fineness and softness requisite for spinning into very small sizes of yarn. The hot summers of Russia and Prussia are also inimical to fineness of fibre, and the bulk of the flax grown in those countries is dry and brittle, and wants that elasticity, pliancy, and oiliness, which are found in the produce of more temperate countries. There is, however, less care bestowed upon the cultivation of flax in these countries than in Belgium or Ireland, and perhaps this, as well as the hotter climate, may tend to produce a coarser fibre. With careful cultivation, flax will flourish over a great range of latitude; but only where the conditions indicated exist can it be produced in the highest degree of fineness, and consequent suitability for conversion into the more delicate textures.

Flowers and Upper Stalks of Flax Plant.

Fibre of Dressed Flax (*Magnified 310 Diameters*).

With regard to soil and cultivation, we could have no better guide than Mr. Charley, whose book on "Flax and its Products in Ireland" contains much valuable information. He tells us that the best soil for flax is a nice dry, sandy loam, or an alluvial soil, not too light, but of medium weight, with a strong subsoil, but not of a clayey nature. With great care, however, a fair crop may be had on other soils not so well adapted for the purpose. The treatment of the soil should depend on its quality, the object to be attained being the production of a fine, deep, dry, and clean bed for the seed. In the case of light soils, it is considered best to plough the wheat stubble in February, or early in March, so as to get a little of the frost. In April it should be well harrowed, and picked clean of any weeds, then sown with seed at the rate of $3\frac{1}{2}$ bushels to the Irish acre, equal to a little over 2 bushels to the English statute acre. The ground should be made as even and flat as possible, in order to insure uniformity of length in the stems of the plant when at maturity. After the seed is sown, which should be done up and down the rig, not across, a fine seed harrow and a light roller should be passed over the field, to cover the seed and finish the plot. When these operations are completed, the seed should be about one inch below the surface. It is considered advisable to sow rather a full quantity, as the greater the number of stems the greater the quantity of fibre. When the seed is sown sparsely, as in cases where the seed produce and not the fibre is the chief consideration, the plants come up stronger and coarser, and bear heavily-branched tops, loaded with seed capsules. Depth of tillage is of great importance, as the roots penetrate far down in search

of the nourishment required by the plant, and if their wanderings be checked the crop suffers. In the case of soils of a medium class, the same treatment as here described will be found to suit, provided the fields are well situated and well drained. Heavy soils require two ploughings and frequent harrowing and rolling to reduce them to even a tolerable condition, and wise farmers as a rule avoid committing flax to ground of this kind.

The seed is the next consideration, and, as already stated, it is an important one, and the best modes of using it are indicated above. Then, the rotation of crops must be kept in view, as on this depends the successful cultivation of flax. The usual system is not to sow two crops of flax on the same soil without an interval between of from six to ten years, so that the land under the ordinary agricultural rotation is regularly receiving from the different manures applied a part of the special nourishment yielded to the flax, and in the time specified becomes again ready to support another crop. In the instructions to flax growers, the Société Linière of Brussels maintains that "above all things the rotation of crops must be scrupulously observed; if seven or eight years be allowed to elapse before again sowing flax in the same field, it is certain that there will be a good crop; but the less the interval between the two crops, the less is the second to be calculated on, either for quality or weight."

In Ireland, the highest authorities seem to be agreed that the best rotation is as follows:—First year, lea; second, oats; third, potatoes and turnips; fourth, wheat, one-half sown with grass; fifth, half hay, one-fourth flax, one-fourth beans. More or less flax than this may be safely grown, at the discretion of the farmer; but flax ought never to be raised on the same soil oftener than once in ten years. If sown the first year after a potato crop, the flax grows too rank to thrive, and besides this the farmer loses the intermediate very profitable crop of wheat, without having any real benefit to counterbalance the sacrifice. When sown after wheat in the manner mentioned, it is really an extra crop, grown without manure, and so in no way an exhaustive or severe crop. If grown oftener than once in ten years, it is no doubt a severe crop. In poor soils not fit for growing wheat, flax may be sown after potatoes with advantage. A difficulty that farmers who have been disposed to give flax a trial have experienced, and, indeed, continue to experience, is a rooted belief in the minds of many landowners that the crop is one that impoverishes the soil. It has been customary in certain parts of Ireland, and also in England and Scotland, to insert clauses in the leases of farms prohibiting the growth of flax. The prejudice is, however, a groundless one; for by following a proper rotation of crops, and returning the waste matter of the flax to the soil in the form of manure, all that is taken away may be restored.

Among the instructions to flax growers issued by the North-Eastern Agricultural Association of Ireland is the following relating to sowing, which illustrates how careful is the treatment required to produce a satisfactory crop:—"The seed best adapted for the generality of soils is Riga, although Dutch has been used in many districts of the country for a series of years with perfect success, and generally produces a finer fibre, but not so heavy a crop as Riga. In buying seed, select it plump, shining, and heavy, and of the best brands, from a respectable merchant. Sift it clear of all seeds of weeds, which will save a great deal of after-trouble, when the crop is growing. This may be done by farmers, and through a wire sieve, twelve bars to the inch. Home-saved seed has produced excellent crops, yet it will be best, in most cases, to use the seed which is saved at home for feeding, or to sell it for the oil mills. The proportion of seed may be stated at one Riga barrel, or three and a half imperial bushels to the Irish or plantation acre, and so on, in proportion to the Scotch or Cunningham, and the English or statute acre. It is better to sow rather too thick than too thin, as with thick sowing the stem grows tall and straight, with only one or two seed capsules at the top; and the fibre is found greatly superior in fineness and length to that produced from thin-sown flax, which grows coarse and branches out, producing (as we have already seen) much seed, but a very inferior quality of fibre. The ground having been pulverised and well cleaned, roll and sow. If it has been laid off without ridges, it should be marked off in divisions, 8 or 10 feet broad, in order to give an equable supply of seed. After sowing, cover it with a seed harrow, going twice over it —once up and down, and once across or angle-wise, as this makes it more equally spread, and avoids the small drills made by the teeth of the harrow. Finish with the roller, which will leave the seed covered about an inch—the proper depth. The ridges should be very little raised in the centre, when the ground is ready for the seed, otherwise the crop will not ripen evenly; and when land is properly drained there should be no ridges. A

stolen crop of rape or winter vetches, or of turnips of the stone or Norfolk globe varieties, may be taken after the flax is pulled. Rolling the ground after sowing is very advisable, care being taken not to roll when the ground is so wet that the earth adheres to the roller."

Having deposited the seed in the earth, the flax grower's next care is to keep a close watch for the appearance of weeds among his crop. In all cases weeds are objectionable, but flax is peculiarly liable to deterioration from their presence. Accordingly, when the plant has reached a height of 5 or 6 inches, and such weeds as may be present have shown themselves, the fields must be gone over with scrupulous care, and every alien growth removed. The weeders must be shod in a way not to injure the flax plants, and in passing over the ground they must work towards the wind, so that the down-trodden plants may have the aid of the breeze in their effort to recover a perpendicular position;—this point is of such importance that, as we shall immediately see, great stress is laid upon it in certain official regulations. When the plant is grown chiefly for its seed, it is usual to allow it to attain maturity; but when the fibre is the chief consideration, it is pulled before it has become quite ripe, the common rule in Ireland being to allow two-thirds of the stalk to become yellow, and not to allow time for the seed capsules to become more than slightly tinged with brown. In the instructions of the Société Linière, above referred to, the following is the directions relating to the proper time for pulling:—"It has been proved that when the flax is pulled between the falling of the flower and the formation of the seed, the fibre is finer and more solid than at any other time; so that unless it is wished to sacrifice the quality of the flax to obtain seed, the former must not wait the full maturity of the latter." The instruction of the North-Eastern Agricultural Association of Ireland, with regard to weeding, is as follows:—"If care has been paid to clearing the seed and the soil, few weeds will appear; but if there be any, they must be carefully pulled. This is done in Belgium by women and children, who, with coarse cloths round their knees, creep along on all-fours. This injures the young plant less than walking over it (which, if done, should be by persons whose shoes are not filled with nails). They should work also facing the wind, so that the plants laid flat by the pressure may be blown up again, or thus be assisted to regain their upright position. The tender plant pressed one way soon recovers; but if twisted or flattened by careless weeders, it seldom rises again. The weeding should be done before the flax exceeds 6 inches in height."

EMINENT MANUFACTURERS.—III.

SIR JOSIAH MASON, OF BIRMINGHAM.

By Robert Smiles.

The teachers of a certain school pronounce in set terms the dictum that "man has always been the creature of the circumstances in which he has been placed; and that it is the character of these circumstances which inevitably makes him ignorant or intelligent, vicious or virtuous, wretched or happy." The progress, conduct, character, attainments, and achievements in life, of some men, furnish startling commentaries on this doctrine. There are instances of even boys, handicapped with ignorance and poverty, who run splendidly the race of life, and rise to become useful, honoured, and influential men, and reach the summit in the business occupation, or profession, they elect to follow. Sir Josiah Mason is just such a man. He was born at Kidderminster, on the 23rd of February, 1795. His parents were worthy and reputable people, though their circumstances were straitened. When only twelve years old, he had the misfortune to lose his father (who died at seventy years of age, and his mother at eighty-two).

The occupations followed by Mr. Mason in his boyhood and youth at Kidderminster, were those of shoemaker, baker, and carpet-weaver, and it can be readily believed that they were but a sorry training for his new life in Birmingham as a metal worker—an entirely new vocation, in which he had everything to learn. His marvellous success furnishes conclusive evidence of his power of adapting himself to circumstances, of his industry, skill, and exceptionally great natural gifts and capacity. Either immediately, or very soon after, he commenced work in Birmingham, he was employed by a maker of jewellery and gilt toys, and remained with him for about ten years. Before the expiry of that time, such had been his assiduity and acquired skill, that

his employer promised him a partnership. The employer's family opposed the proposal, and the master died without its being carried out. The successors to the business offered Mason a liberal salary to remain as manager, but feeling that he had not been treated honourably, he refused to accept the engagement, and left the concern. He had, however, become to some extent known, and had no occasion to despond, men of his stamp being in demand in Birmingham. An acquaintance directed him to Mr. Samuel Harrison, of Lancaster Street, split-ring maker, to whose business Josiah Mason ultimately succeeded, under the style and title of Mason, late Harrison. The attachment between Mr. Harrison and Mr. Mason from almost the commencement of their connection, was of the most affectionate character, and memorials of his deceased friend in tools, presses, and other articles, are preserved and cherished by Sir Josiah in his house and in the Orphanage at Erdington, with the most loving care. Harrison was a man of excellent parts. He had a high sense of honour, a warm temperament, and was possessed of considerable scientific knowledge and handicraft skill. He was the friend of Baskerville, the eminent printer, and of the distinguished Dr. Priestley, with whom he made scientific experiments. Mason was not probably very fastidious, when he reached what Burke called "the toy-shop of Europe," as to the branch of metal working he would take up. He had a wide choice, but whether he betook himself to making the particular instrument—the pen—because it is "mightier than the sword," we know not. At any rate, he did so, and became one of the "largest makers" of steel pens in this country—probably in the world.

How Mason began to make steel pens was in this wise. The late Mr. James Perry, of Red Lion Square, London, a man of great energy and perseverance, was probably the first maker of steel pens "for the market." It was not, we believe, earlier than 1825 that he commenced to push the sale of these articles by travellers and advertisements. About 1828—three or four years after he had joined Mr. Harrison—Mr. Mason saw a card of Perry's pens in a stationer's window in Birmingham, price 3s. 6d. each. He purchased one, and after examining it, came to the conclusion that he could improve upon it. He forthwith made three pens, and sent them to Mr. Perry in London, who within two days arrived at Lancaster Street, for conference with the man that could make better pens than his own. The result was an arrangement for Mason to make the pens, and Perry to sell them, the goods to be stamped with Perry's name, or with the title of the "Perryan Pen." It may here be mentioned that, although Sir Josiah Mason has been an extensive manufacturer of steel pens for nearly fifty years, he has never been known as such by the general public, the names of the traders whom he supplied, and not his own, being stamped upon his productions.

Mr. Joseph Gillott commenced his career as a pen maker about the same time as Mr. Mason. It was an entirely new department of metal working, requiring specially adapted machine tools and other appliances. Mason and Gillott appear to have contrived their own methods, for it is remarkable that their names scarcely appear in the Patent Office Records. A considerable time after the trade was fairly established, steel pens were sold at 1s. each. But now a gross can be had as low as $2\frac{1}{2}$d., the prices for nibs, wholesale, ranging from that figure to about 1s. 6d.; and for barrel pens, from 7d. to 30s. per gross. Since 1830, great improvements have been effected in the machine tools and processes employed in pen making; the quality of the goods has been vastly improved, the production has been enormously increased, and the use of the article greatly extended. Sir Josiah Mason has taken a leading part in effecting this revolution. When he retired from the Lancaster Street Works, his people were rolling 5 tons of steel weekly, and had constantly about 60 tons of pens in different stages of manufacture.

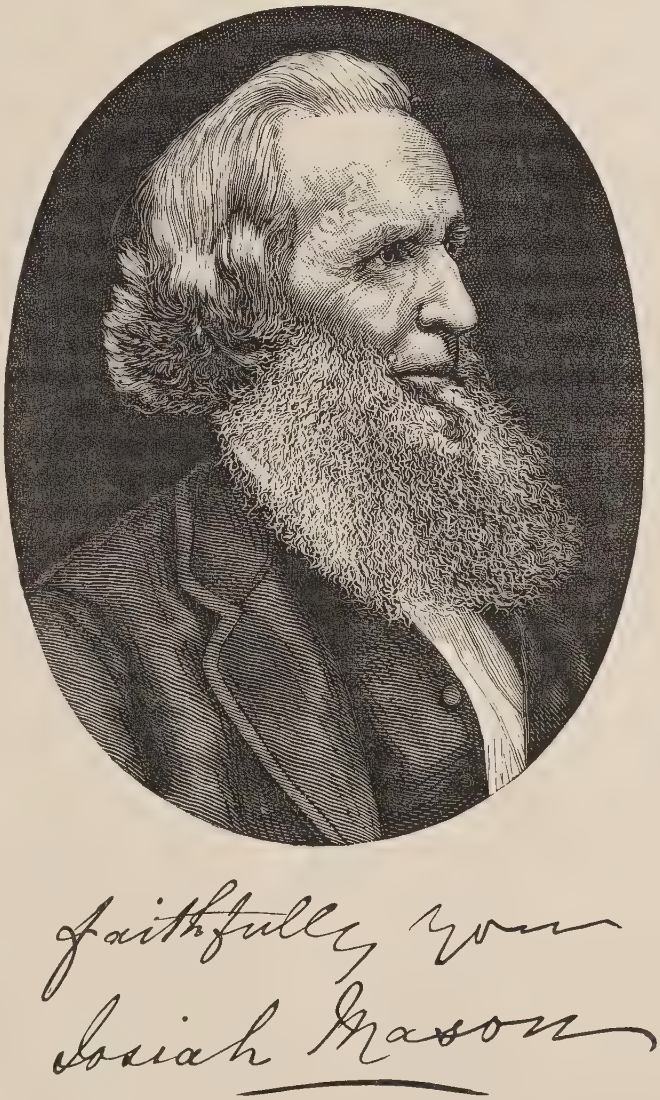
Mr. G. R. Elkington, about 1840, commenced operations as an electro-plater, and inaugurated a complete revolution in the plating trade. In 1842, Sir Josiah joined him as partner, and took an active share in the design and erection of the magnificent establishment in Newhall Street. Many friends endeavoured to dissuade the firm from prosecuting their enterprise. They carried on the business for a considerable time at a loss; but by skill, perseverance, and good management, surmounted all obstacles, overcame all difficulties, recovered their losses, and had their efforts crowned with triumphant success.

In 1850, Mr. A. Parkes, chemist to Elkington and Mason, an accomplished metallurgical chemist, took out a patent for an improved method of copper smelting: the partners in Elkington and Mason, the electro-plating firm, entered into another partnership as Mason and Elkington, for the copper smelting business. They erected works at Pembrey, in South Wales, which was then a small village; but in consequence of the establishment of the works,

rapidly increased in importance. A school for the workmen's children was built very soon after the works were opened. The school, in the provision of which Sir Josiah Mason took the leading part, has always been to him an object of the most lively interest and watchful care.

When Mr. G. R. Elkington died, Sir Josiah retired from the electro-plating firm of Elkington and Mason, and the copper-smelting firm of Mason and Elkington. Subsequently he retired from the extensive pen manufactory, steel and other metal small-ware works in Lancaster Street, which are now carried on by a limited liability company. But he has succeeded in establishing an extensive refinery for the manufacture of nickel and other metals.

The eminently successful career of Sir Josiah Mason, highly honourable to himself, furnishes material for an interesting study; but the crowning glory of his life and character is to be found less in his success than in the results, personal to himself, that have proceeded from it, in the enlightened munificence and exalted charity he has displayed in the application of his wealth.



Sir Josiah Mason has made a notable contribution to the solution of the problem—how a man may best dispose of his accumulated wealth for the benefit of survivors and posterity. The hardships of his own early life, and the disadvantages under which he laboured from defective education, or rather the want of education, probably gave direction to Sir Josiah's benevolence in founding and endowing an Orphanage, Almshouses, and a Scientific College, to be identified with his name, and which will prove his monuments in all coming generations.

The Orphanage, near Sir Josiah's residence at Erdington, about five miles to the north-east of Birmingham, is built for the accommodation of 300 boys and girls. Although a careful and exact business man, Sir Josiah would not allow any consideration of cost to interpose in making the whole as perfect as possible. The cost was about £60,000. It is endowed with land and building estates of the estimated value of £200,000. The building has a very picturesque and imposing appearance. The Orphanage is managed by trustees appointed by the founder; afterwards they will be appointed, subject to certain conditions provided in the trust-deed, by the Town Council of Birmingham. The Institution was opened in August, 1869, and, as characteristic of the unobtrusive founder, without ceremony of any kind.

Sir Josiah, immediately after the completion of the Orphanage, entered upon the elaboration of his other and greater philanthropic project — the Scientific College, for thorough systematic scientific instruction, specially adapted to the practical, mechanical, and artistic requirements of the district. The founder provides by the trust-deed that the curriculum must include the following:—Mathematics, abstract and applied; physics, mathematical and experimental; chemistry, theoretical, practical, and applied; natural sciences, especially geology and mineralogy, with their application to mines and metallurgy; botany and zoology, with special application to manufactures; physiology, with special reference to the laws of health; English, French, and German languages. The trustees may include such other subjects as they may think necessary to a course of thorough systematic scientific instruction,

adapted to the practical, mechanical, and artistic requirements for the time being of the manufacturing and industrial pursuits of the midland district, and of the boroughs of Birmingham and Kidderminster, specially including mechanical drawing and architecture, but excluding mere literary education and instruction. Six trustees have been appointed by the founder, and hereafter the Town Council of Birmingham will have power to appoint other five, but the number of trustees must never exceed eleven. They must be laymen and Protestants, but no religious test is to be imposed upon the principal, vice-principal, professors, or teachers. The property dedicated in perpetuity by Sir Josiah Mason for the establishment and endowment of the Orphanage and the Scientific College will not be less than £370,000.

In fine, Sir Josiah Mason is a man whom his fellow-townsmen and all who know him delight to honour, and whom they do honour, but whose diffidence makes him shrink from the acceptance of any public manifestation of such regard. On the occasion of the opening of the Orphanage, he was requested to sit for his portrait to be painted by a first-rate artist at the public expense. To silence respectful importunity, he gave a reluctant consent, which he afterwards, on reflection, withdrew. The well-earned honour of knighthood was one that he accepted, but neither desired nor sought. Although full of anecdote, and highly interesting in his conversation in private, he uses in public the "eloquence of silence." He is an illustration of the saying, that "modest men are dumb;" but, withal, his modesty is "a candle to his merit." He is little known in connection with public affairs, and avoids acceptance of honourable offices that are open to him. On one occasion, at least, he departed from what seems to be a rule of life with him. In 1866, when the disastrous failure of the Birmingham Banking Company occurred, he was earnestly assured that his acceptance of the post of chairman of the new company would render essential service to the shareholders, and he reluctantly accepted office on this representation.

Sir Josiah Mason is a strict economist in time and money, and has earned his position by the exercise of such humble but by no means common qualities as industry, honesty, and perseverance, and by making the best use possible of the faculties with which he is endowed, and of his opportunities for promoting the welfare and prosperity of himself and others.

The portrait of Sir Josiah Mason is taken from a photograph by Mr. H. Penn, of Birmingham.

WOOL AND WORSTED.—IV.

WORSTEDS AND WOOLLENS: WHAT ARE THEY?—FIRST PAPER.

By Walter S. B. McLaren, M.A., Worsted Spinner.

THERE are very few persons not engaged in some branch of the wool trade who know technically what worsteds and woollens really are, or what is the difference between them. Among the general public there is, no doubt, considerable ignorance as to the materials of which things are severally made. It is related that after a party of strangers had been taken through a cotton mill, and had been shown all the processes through which the cotton passed before the goods were finished, one of the number, noticing some bales of the raw material, went to them, and taking out a handful of cotton, exclaimed, "So this is really the wool just as it comes from the sheep's back!" The difficulty in the case of worsted is not, however, to know of what it is made. It may be assumed that most persons know it is spun from wool. Yet, so recently as 1875, the worsted spinners were astonished to receive a circular, signed by Her Majesty's Inspectors of Factories, asking, among other questions, "Do you spin worsted, or wool?" It would be uncharitable to suppose that the gentlemen who signed that circular did not know of what worsted consisted, and that the correct answer for every spinner to give would be:—"I spin both: I spin wool into worsted." Hence the question, as it stood, was absurd. The real meaning, of course, was, "Do you spin worsted or woollen yarn?" and though each spinner could tell at once whether he spun worsted or woollen yarn, yet if he had been called upon to define the meaning of the two words, and to state the difference between cloths made of the two materials, he might not have found it so easy. It can therefore hardly be expected that persons not engaged in the trade should know what worsted really is, and the distinction between it and woollen

yarn or cloth. But as it is desirable that the difference should be known, it is necessary to explain what are the supposed and what are the real points of difference between worsted and woollen yarns.

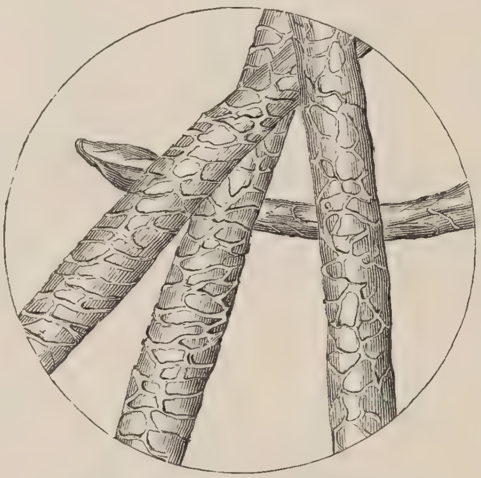
It is popularly said that worsted is made of long wool which is combed; and that woollen yarn is made of short wool which is carded. As the processes of combing and carding must be frequently mentioned in any account of worsted and woollen yarn spinning, it is requisite to define briefly what they are. The wool upon a sheep's back is more or less matted, and the fibres require to be separated and prepared for spinning. Combs and cards are two kinds of machines used for this purpose. The card, or carding machine, which derives its name from the Latin *carduus*, a thistle, consists of a number of cylinders of various sizes, covered with thousands of short wire pins, which revolve rapidly. The wool is drawn in between the two first cylinders, and is gradually worked forward till it comes out at the other end of the machine, all the fibres having, in the meantime, been separated from each other by the action of the pins on the revolving cylinders. By this means all the knots and lumps which were in the wool are opened; but the wool does not come off the card with the fibres stretched out lengthways, as is the case when it has been combed. Nor is the very short wool separated from that which is longer; it all remains mixed together. When it is desired to separate this short wool with the object of obtaining a smoother thread (for it must be remembered that upon every sheep long and short wool grow together), the comb must be used. This separation is obtained by placing the wool upon rows of steel pins arranged in a circle. As the circle revolves, the long wool is first drawn off by a pair of rollers, and the short wool which remains is removed in a similar way, and kept separate. The long wool thus drawn off, the fibres of which lie smoothly side by side, is called the "top," while the short wool, or refuse, is called the "noil." The wool, however, needs some preparation before it can be combed, and this preparation consists either in carding it, as above described, or in passing it through what are known as "preparing boxes," which will be afterwards alluded to.

It is supposed, then, that all long wool is combed and spun into worsted, while all short wool is carded and spun into woollen yarn: and that in this lies the essential difference between the two classes of yarns. This opinion is endorsed by almost every writer upon the subject. Nevertheless, it is quite inaccurate at the present day, although, no doubt, there was a time when it was substantially correct. Even then, however, it was an unsatisfactory definition, on account of the vagueness of the terms "long" and "short," as may be seen, for example, in Dr. Ure's description of these two kinds of wool. In his "Dictionary of Manufactures," he says that long wool varies from 3 to 8 inches, while short wool is seldom longer than 3 or 4 inches. At the present time, however, combing wool for worsteds varies from less than 2 inches to more than 20 inches in length, while carding wool for woollens varies from what may be said to be no length at all up to about 5 inches. Thus, for example, a large quantity of Australian or "Botany" wool is combed, in which a considerable proportion of the fibres in the "top" (or ball of combed wool) are not more than an inch long, while in the "noil" (or refuse of short wool) the fibres are of course still shorter. In rough woollen cloths, on the other hand, made of Cheviot and half-bred wools, the fibres are often 5 inches long. It is clear, therefore, that the distinction between worsteds and woollens depending on the length of the fibre is no longer tenable. Nor is the distinction that the one is combed and the other carded satisfactory. All woollen yarns are carded, or, to use another name, "scribbled," but a very large proportion of worsted yarns are also carded. There may be said to be three main classes of worsted yarns, which, however, to some extent overlap each other. Lately, a fourth class has been invented, which is of a curious character. The first class is composed chiefly of long English wool, which is combed after having passed through what are known as "preparing boxes." Of the second class, yarn made of Botany wool may be considered representative, for the wool is short, and is first carded and then combed. Carpet yarns and coarse *fingering* or knitting yarns compose the third class, and are made of wool of various lengths, which is carded without being combed afterwards. We have seen wool more than a foot long used in this way without much detriment. The fourth class is known as knickerbocker yarn, and is made of wool mixed with silk noil, or waste. To make it, the wool is first combed by itself, and afterwards carded, to insure the thorough distribution of the silk noil, which stands out in small lumps and knots on the surface of the yarn. These different classes cannot always be kept distinct. The top of combed English wool may be mixed with a top of carded Botany to give it a finer quality; or the carded

carpet yarn may have in it some combed wool to make it more level, and other combinations may be made; but the idea that worsted yarn must be combed, and that only short wool can be carded, is entirely erroneous; and a more accurate distinction between worsted and woollen yarns must be found.

By some persons it is supposed that this distinction lies in the spinning-frame: woollen yarn being spun upon the "mule," and worsted upon the "throstle." The chief characteristic of the latter spinning-frame is that the yarn is twisted and wound upon a bobbin as fast as it is delivered by the pair of rollers which draw it out; and as this pair of rollers revolve constantly while the spinning-frame is in motion, the principle of the "throstle" frame is known as "continuous drafting." The characteristic of the mule spinning-frame, on the other hand, is that the thread is drawn out by the rollers for about two yards before it is wound on to the bobbin, being kept stretched out by means of the spindle and bobbin on which it is to be wound travelling away from the rollers on a "carriage." When the "carriage" has gone the full length of its journey, the drawing-out rollers stop and allow the yarn to be twisted as much as may be necessary, after which it is wound on to the bobbin as the carriage again travels to the rollers. In consequence of this stoppage of the rollers, the drafting, or drawing out of the yarn, is not continuous. It is believed that this mode of spinning is most suitable for woollen yarn, while the principle of continuous drafting is most suitable for worsted. But this, too, is a mistake. Woollen yarn has, we believe, been spun on the mule since that machine was invented; but a spinning-frame upon the throstle principle of continuous drafting has recently been made which is said to be suitable for woollen yarn.

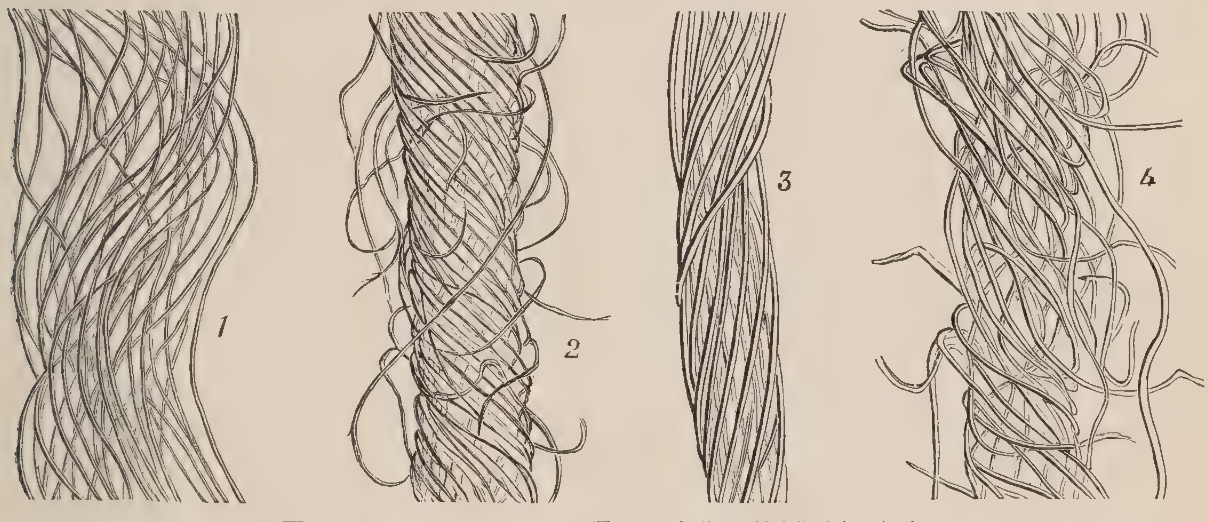
Worsted, however, is spun upon both the throstle and the mule: the latter frame being almost exclusively in use on the Continent, where it is found to be suitable for spinning combed as well as carded wool. As this distinction, therefore, is untenable, we turn to another, which is generally believed to be correct—viz., that woollen fabrics are "fulled," or milled, or felted, while those made of worsted are not. This is still an unsatisfactory definition, because it deals with the cloth, whereas it is obvious that whatever difference there may be must exist in the yarn, seeing that both sorts of yarn can be woven in the same way. Apart, however, from this objection, which is fatal, the definition is not exhaustive. There are, we believe, some woollen cloths which are not milled, but merely scoured to remove the oil that has been used to help the spinning. On the other hand, there are worsted fabrics (such as cloths for coats), some of which are milled to give them greater softness. There are also mixtures, of which the warp may be worsted and the weft woollen, and these may or may not be milled. But though this definition is even more unsatisfactory than those previously considered, it is in connection with it, although indirectly, that the solution of the problem is to be found.



FIBRE OF WOOL (*Magnified 30 Diameters*).

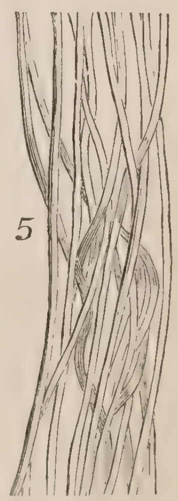
The difference between worsted and woollen depends on the arrangement of the fibres in the thread, and this indirectly depends upon the general belief that the fibres arranged in one way are less suited for felting than if they are arranged in another; but whether this belief has any justification in fact is doubted by some persons. To make this clear it is necessary to state briefly what felting or milling is, and what property wool possesses which allows it to be felted. When a piece of cloth is woven, each thread of warp and weft can be distinguished, if not by the naked eye, by the aid of a magnifying glass. This gives the cloth a somewhat bare look, and if the wool of which the yarn is made be very short, the cloth is comparatively weak. In certain cloths it is desirable to avoid this, and to make the stuff into one compact piece. For this purpose the cloth is put into water and pounded with large hammers of wood, called "stocks," or it is passed through rollers under a heavy weight. By these means the fibres of wool shrink and are drawn closer to each other. They become matted and locked fast in each other. The original form of the cloth is lost, and the separate threads can no longer be seen. Instead of a piece of cloth similar to that which was put in, there comes out from the stocks (if the felting has been continued long enough) a piece apparently quite different. It has lost in length

and breadth, but has gained in thickness, and now appears a matted, solid piece of woollen stuff. What is it in wool which permits this operation? If hair were to be woven and milled under the stocks, it would not felt or mat together in the same way, or only to a very slight extent. The difference between hair and wool is that a hair has a smooth surface, comparatively free from jagged edges or serratures of any size, and lies straight; while a fibre of wool is more or less waved, and is covered with serratures. A fibre of wool, in fact, may be likened to a serpent's skin or to a fir-cone covered with scales. The serratures, or saw-like teeth, representing these scales, overlap each other, and present innumerable little points, which act as hooks. They are extremely small, and in a fibre there are said to be from 1,200 to 3,000 per inch. When wool is spun, these serratures to some extent fit into or catch each other, and help to bind and lock the fibres together; consequently, other things (such as length, quality, &c.) being equal, wool which has many serratures will spin better than wool which has few.



Woollen and Worsted Yarns (Threads) (*Magnified 50 Diameters*).
(1) 30s Worsted made of Fine Wool; (2) 30-skein Woollen made of Fine Wool; (3) 30s Worsted made of Strong Wool; (4) 28-skein Woollen made of Cheviot Wool.*

It is believed that wool with many serratures is best suited for felting, and that it is on account of its jagged and serrated surface that felting is possible. There are, however, some kinds of wool which throw doubt on this, and show that some other qualities are required to make wool felt in addition to its serrated surface. Among these are Cape of Good Hope, Odessa, and Buenos Ayres wools. The first named is fine in quality and has a very large number of serratures; yet it is found to be, of all wools, perhaps the most difficult to felt. Odessa wool, which is also well serrated, can hardly be felted unless mixed with wool from other countries; and the same may be said of that from Buenos Ayres. Peruvian wool, on the other hand, which is stronger and longer, and not so well serrated, appears to be especially easy to felt. Hence it may be considered certain that the serrated surface alone is not enough to give wool its property of felting. What the other requisites are cannot be stated with certainty. It is supposed that the country, the climate, the nature of the soil, and the food of the sheep, affect the wool, and make it more or less suited for felting. But beyond these somewhat vague surmises, nothing is positively known. Persons engaged in the trade are content to know that some wools can be felted better than others, without inquiring into the reason of the difference. No thorough scientific investigation has hitherto been made into the nature of various classes of wool; but it may be hoped, as technical schools for instruction in textile industries have been founded, that some definite information



36s Lustre Worsted.

* Nos. 1—4 are specimens of worsted and woollen yarns, showing the difference in the arrangement of the fibres in the two classes of threads. No. 5 shows how very straight good worsted can be made, and how evenly the fibres of wool lie. Worsted is numbered according to the number of hanks (= 560 yards) in a pound. Thus in 30s there are 30 hanks of 560 yards each to a pound.

will be obtained on this subject. It may be said, however, that as a rule fine wool is best suited for felting, because strong wool seems to partake more of the nature of hair—the strongest sort of all, that which grows on the hind quarters of badly-bred sheep, being known technically as "cow-tail." Nevertheless, all wool can be felted to some extent; and as it is almost invariably intended that woollen cloth should undergo that operation, it is necessary to prepare and spin the yarn in such a way that felting may be facilitated; and in consequence of the shrinking and matting of the cloth which thereby take place, any slight imperfections, such as unevenness, are not easily seen.

But in worsted fabrics it is different. They are not intended to be felted, except in the case of some worsted coatings, and even then only very slightly. It is, therefore, of the highest importance, except in the knickerbocker variety, that the yarn should be level, smooth, and free from lumps of any kind. To attain this end how must the fibres be arranged? To have a level thread, and a smooth surface on the worsted fabric, all the fibres of wool must lie in the same direction in the yarn. That is the essential characteristic of a worsted thread. If the fibres are doubled up, or crossed, or tumbled about in any way, it is impossible to have a really even thread. To insure this levelness it is necessary in the finer yarns to remove, by means of combing, all the very short fibres, and the little knots and lumps which are inseparable from them. In the coarser sorts, such as carpet yarns, where this high degree of excellence is not needed, and where it is necessary to have a soft bulky yarn, it is not desirable to remove the short fibres by combing; but yet the wool is put through certain processes to insure that, as far as possible, the fibres shall all lie in one direction. Now, compare this with a woollen thread. In it, instead of lying smoothly and having a regular twist to bind them together, the fibres are crossed and doubled in every direction. The thread is consequently somewhat rough, and many loose fibres seem to stand out from it. These are of great use in assisting the felting of the cloth, as they lay hold of each other, and knit the different threads into one piece. The beauty of worsted is to have as few of these loose fibres as possible, and, at the same time, to have a round, level thread, because the thread is seen in the woven fabric. On the other hand, as the woollen cloth is generally intended to be felted or milled, the fibres must be arranged in such a way as to assist that operation; and it is supposed that when the fibres of wool lie in all possible directions in the thread, and when many of them stand out from the surface of it, their serrated surfaces are more exposed than when they are smoothly stretched out in parallel lines. In other words, by this rough arrangement of the fibres, they get hold of each other better, and lap round each other more firmly in the felting.

It must not, however, be supposed that it is the felting or milling which entitles a particular yarn or cloth to be called woollen. A woollen cloth is made of woollen yarn, whether it be milled or not; and similarly a worsted cloth is made of worsted yarn, however much it may be milled. If it were considered necessary—which it never is—to mill fabrics of which both the warp and weft were spun from wool 15 or 18 inches long, it could be done. In the same way, too, any fabric made of mohair could be milled, for mohair is a wool rather than a hair, as its name seems to imply. The word mohair evidently comes from the same source as its equivalents in French, German, and Russian, *moire*, *mohr*, and *mor;* and is, according to the etymologist Skinner—not a very good authority, however—derived "ab orientale voce 'moiacar' species cameloti" [from the Eastern word *moiacar*, a kind of camelote, a cloth originally made of camel's hair]. There are, of course, worsted goods which are partly made of cotton or silk, or even China grass, but of these it is not necessary to speak at present. They are usually called worsted, in spite of their mixture, not on account of it; and they prove, for the present argument, that any attempt to define the difference between worsted and woollen in the cloth instead of in the yarn would be unsatisfactory. To understand the difference between the two classes of yarn, it is necessary to have some idea of the way in which each is made, and it will then be seen that it is according to the manner in which the fibres are arranged that a thread is known as worsted or woollen.

SHIP BUILDING.—V.

THE USE OF IRON IN SHIP BUILDING.

THE use of wrought iron for constructional purposes may be said to date from the years 1783–84, when Cort introduced his patent processes for puddling and rolling iron. By these simple but original devices, the manufacturer was endowed with the power of producing iron plates of various sizes and thicknesses, as well as bars of varied sectional forms. Until the period named, *hammering* was the only process by which wrought iron could be shaped from the rough mass into plates and bars; and as a consequence, the material was but little used. Sir William Fairbairn, speaking of the changes resulting from Cort's inventions, said:—"When Watt was engaged with his steam engine, the only material at his command for his boiler, in which to generate steam, was hammered copper plates or cast iron; hammered iron plates were occasionally made, but seldom used, and it was not until the introduction of rolls that anything in the shape of iron plates could be obtained." It may be safely said, therefore, that the subsequent developments of the steam engine, of iron ship building, of bridges, railways, and other structures in which wrought iron is largely used, have been rendered possible by the practical effect given to the invention originated by Cort. And it is to be regretted that a man to whom Great Britain and the world at large are so deeply indebted should have reaped so little personal advantage from his inventions.

Engineers were the first to make extensive use of rolled iron plates, in the construction of steam boilers. So early as the year 1786 such boilers were built; and in the following year there is a record of the existence of an iron canal boat—the first iron vessel of which any account is extant. This boat arrived at Birmingham with a cargo of about 23 tons of iron, her own weight being 8 tons. She was 70 feet long and $6\frac{3}{4}$ feet wide; was built of iron plates $\frac{5}{16}$ths of an inch thick, and had wooden stem, stern-post, and beams. It is further stated that she was "put together with rivets, like copper or fire-engine boilers." Probably none of the spectators who witnessed the arrival of this little vessel dreamed that she was the pioneer of a new system of construction, that was to extend to all classes of ships, and revolutionise the art of ship building. Yet, so it was, although the change did not begin to show itself for thirty years, outside the special class of vessels where it originated. On the canals of Staffordshire, iron canal boats were generally used at the commencement of the present century, and their efficiency and durability soon led to their employment in other districts. Some of these vessels continued at work for thirty or forty years, and a few for even a longer period. One most remarkable case is that of the *Vulcan*, built on the banks of the Monkland Canal, near Glasgow, in 1818, and found to be at work quite recently, after sixty years' service.

In 1821 it was proposed to extend the use of iron hulls to steamers designed for service on rivers or coasts. One of the promoters of this scheme was the gallant officer afterwards so well known as Admiral Sir Charles Napier. It is a significant fact that the first iron steamer was constructed by the Horsley Company, in Staffordshire, and not by any ship builder at one of our sea-ports; iron was evidently regarded at that time with anything but favour by shipwrights, whose training and precedents excluded all other materials but wood. The *Aaron Manby* was 120 feet long, and 18 feet broad, with engines of 80 horse-power. Having been erected at Horsley, the *Aaron Manby* was taken to pieces and brought to London, where she was finally put together and equipped. Having shipped a cargo of iron and linseed, she started for Havre, under the command of Captain Napier, and afterwards ascended the Seine to Paris, where her arrival caused a great sensation. Her success led to the construction, in France, of other iron steamers, which, with the *Aaron Manby*, were employed on the Seine. Although the *Aaron Manby* crossed the Channel, she was not intended for sea-going purposes, and was essentially a river steamer. This was true also of the next iron steamer built in England, for service on the river Shannon. Designed and fitted together at Horsley, she was taken, in pieces, to Liverpool and there completed, crossing the Irish Channel and proceeding to her destination in 1825. This vessel was the pioneer of another flotilla, and she remained at work for a very long period—more than thirty years. One of her successors on the Shannon had the honour of being the first iron vessel wholly built at Liverpool: 1829 was the date of her construction, and it is worth notice, as fixing the period when iron ship building properly so called began to be practised in English sea-ports. From that time onward, the progress of the new industry has been

continuous and gradually accelerated; until at the present time we find it almost displacing wood ship building in the United Kingdom, making inroads upon wood elsewhere, and only holding a subordinate place in countries which, like Canada, are rich in timber, but have their iron manufacture imperfectly developed.

In 1830, the late Sir William Fairbairn first turned his attention to the construction of iron vessels, with special reference to the design of canal boats of high speeds that should compete with the railways then about to be undertaken. Four such vessels were built at Manchester for service on the Forth and Clyde Canal, and some of these, after passing through the canal from Manchester to Liverpool, made the passage to Greenock. A coasting steamer was also built at the Manchester works, in 1831; and the success of these undertakings induced Fairbairn to enter business as a ship builder. Selecting London as the seat of his new enterprise, he established a yard at Millwall, in 1835, and continued at work there for thirteen years, building more than a hundred vessels, some of which were of large size. The ill-fated *Megæra*, whose loss formed the subject of inquiry by a Royal Commission in 1872, was one of the largest vessels built by Fairbairn; but the undertaking did not prove commercially successful, and was abandoned. It should be added that although not remaining personally engaged in ship building, Fairbairn continued to the last to watch and aid its developments: his experimental investigations and numerous suggestions are still of great value to the iron ship builder, and his name will always be held in honour. Combining, as he did, the professions of civil engineer and ship builder, Fairbairn made his experience in the one available for improvements in the practice of the other. For example, the experiments which preceded the construction of the Britannia Tubular Bridge, were intrusted by Mr. Robert Stephenson to Fairbairn, partly because of his acquaintance with iron ship building, and his possession of special plant; but from those experiments have been derived some of the most valuable principles since embodied in the structures of iron ships. The "cellular double bottom," as a source of strength and safety to iron ships, is a direct deduction from wrought-iron bridge construction; and methods of riveting devised for bridges have, with some modifications, been of advantage to iron ships.

THE "GREAT BRITAIN."

About the same time that Fairbairn commenced work, another famous ship-building firm was started at Liverpool—that of the Messrs. Laird. One of their earlier vessels had the honour of being the first iron steamer that accomplished a long sea voyage. She was named the *Elburkah*, and was only 70 feet long, 13 feet broad, and $6\frac{1}{2}$ feet deep. Her skin was formed of plates only $\frac{1}{8}$th and $\frac{1}{4}$th of an inch in thickness, and she weighed about 15 tons, exclusive of her engines and outfit. Her engines were of 16 horse-power, and her draught of water only $3\frac{1}{2}$ feet. It was, no doubt, a daring venture to navigate such a vessel from Liverpool to the Niger, but she performed the voyage successfully, and gained a reputation for seaworthiness. After making two ascents of the Niger, she was beached and abandoned, having served the purpose for which she was built. Her success, doubtless, did much to extend the employment of iron ships on *over-sea* voyages, which up to that time had been performed exclusively by wooden ships. Such voyages were then considered impossibilities for steamers, the sphere of whose operations was limited to rivers or coasting; but simultaneously, in 1838, both of these opinions were shown to be erroneous by the hard logic of facts. In that year the *Sirius* and *Great Western* steam-ships crossed the Atlantic, and opened up a traffic which has since attained gigantic proportions; while the first iron sailing-ship, adapted for the most distant voyages, was launched, and appropriately named the *Ironsides*. By this time it was generally acknowledged that iron ships could be built with sufficient strength to withstand any weather; but while their seaworthi-

Iron Ship in Frame on the Stocks, Messrs. Samuda's Yard.

ness was admitted, there remained the very serious objection of the deviation of their compasses—an objection which would have been fatal to the general employment of iron vessels, had not means been devised for correcting the compasses, and insuring safe navigation. Of the many workers in this important field, we can only name one of the earliest and most eminent—Sir George Airy, the Astronomer Royal, who not merely corrected the compasses of the *Ironsides*, but devised a simple and inexpensive method applicable to all iron ships. Compass correction has now grown so much a matter of course, that it may astonish some readers to learn that only forty years ago the subject was regarded as one presenting insuperable difficulties, and preventing the possible employment of iron ships on distant voyages. Cases have, undoubtedly, happened in which errors of the compass have been the cause of danger or disaster, but they are comparatively few and far between. Intelligence on the part of the officers of iron ships, and proper care on the part of those charged with adjusting the compasses before a ship leaves port, ought to render the repetition of such accidents impossible. The most difficult cases to be dealt with are those of armoured ships, with great masses of iron bolted on the sides of their iron hulls, and with heavy guns, which, when fired, cause a serious alteration in the compasses; but even these cases are successfully treated by officers charged with this duty by the Admiralty. It would be difficult to point to any case where science has been of more direct benefit to practice than that which has just been under our consideration.

Iron ship building had become well established in other ports besides Liverpool and London, by the time the *Ironsides* was built, the Clyde being a centre of the industry. In the year 1839, a great step in advance of all preceding ships was, however, taken by beginning at Bristol the construction of the famous iron steamer, the *Great Britain*. Mr. I. K. Brunel was the prime mover in this enterprise, and the impetus thus given to the application of sound principles of construction to iron ships was most considerable; it is scarcely necessary to add that Mr. Brunel was not a ship builder, but a civil engineer. This fact may have helped rather than hindered progress, for as a civil engineer Mr. Brunel was familiar with the use of wrought iron in structures, and not being a ship builder he was untrammelled by traditions or prejudices derived from the practice of builders of wood ships. Any one who reviews the structural arrangements of the earlier iron ships cannot fail to remark the close imitation of wood ships in the arrangements and forms of the various parts of the structure. Many features which were unavoidable with wood, but which were very objectionable, as well as unnecessary, with iron, were retained in the earlier ships; and there was frequently a want of appreciation of the superior qualities of iron as a material for ship building. The *Great Britain* was a protest against such servile copying; and it has been well said that "in the construction of the hull, instead of a mere imitation of the arrangements of the timber in wooden ships, the proper distribution of the material to receive the strains that would come upon it was carefully considered." Remembering the date of her construction, the vessel is indeed most remarkable in her structure, as well as her dimensions. She was 322 feet long, 51 feet broad, and of 3,000 tons displacement; was propelled by a screw, had a "balanced" rudder, and surpassed all her competitors in speed, making the passage from Liverpool to New York in the then unprecedented time of from 12 to 13 days. Her very misfortunes supplied weighty arguments in favour of the use of iron hulls; for no wooden ship could have survived the exposure to which she was subjected during a whole winter ashore in Dundrum Bay, and have been repaired at such comparatively moderate cost after she was floated. Her repairs were completed in 1851, and with unimpaired strength the ship was once more sent to sea, this time on the Australian line, where she remained at work for nearly a quarter of a century, and obtained a great reputation for speed and seaworthiness. She now (1878) lies in the docks at Birkenhead, and is by no means past service, although nearly forty years old. The improvements effected in steamers of more recent construction place her under unfavourable conditions for competition, and probably account for her non-employment.

The importance which iron ship building had attained in Great Britain in the year 1842 is evidenced by the fact that the French Government deemed it advisable to send over an able officer to inspect and report on the various establishments. This Report, by M. Dupuy de Lôme, gives us glimpses of the methods of work then common in England, and of the condition of the iron manufacture at that time. London, Liverpool, Glasgow, and Bristol where the chief ports visited, but nowhere was so much of interest to be seen as at the last-named port, where the *Great Britain* was then in progress. From this Report a few facts may be

gleaned, illustrating the differences that have arisen during the last thirty years in the means at the disposal of the iron ship builder. Large forgings for the keels, stems, and stern-posts were not then procurable, or were very expensive, and in lieu of them combinations of plates were used, such combinations being frequently very weak. The "ribs," or transverse frames, had to be formed in several lengths, whereas the angle bars used for the purpose can now be procured in much greater lengths. The plates used in the skins were of very small dimensions as compared with those now in use: lengths of 7 or 8 feet, and breadths of $1\frac{3}{4}$ or 2 feet, were formerly thought considerable; now it is not uncommon to produce plates 4 and 5 feet broad, and 14 or 16 feet long. Deck beams or girders were at first made of wood in iron ships; when iron came into use, the beams had to be formed by riveting angle bars and plates together, but now the iron manufacturer gives to the ship builder a choice of so many sectional forms of iron beams and bars, that the preparatory work of combination is almost entirely dispensed with in constructing decks and platforms. In passing judgment upon the skill of the early iron ship builders, their inferior appliances and facilities should therefore be always borne in mind. They made a good, if not always the best, use of the means at hand, and out of their requirements and suggestions grew most of the improvements in iron manufacture and ship-yard machinery of which the benefits are reaped at the present day.

From the first, as we have shown, iron ship building was closely associated with engineering, and iron ship yards were furnished with special plant and machinery. A few ship builders were sufficiently alive to the future of the new material as to enter into the earlier competitions with engineers such as Fairbairn; but even these employers had to seek their workers in iron amongst the boiler makers, fitters, and other trades which had sprung up in connection with the construction of engines. The shipwrights clung to their ancient handicraft, and gradually passed, from being the principal tradesmen in ship building, to the subordinate place they still occupy in private yards. The traditions of wood ships, however, could not be shaken off entirely by the builders of iron ships, even when they were engineers. For many centuries wood ships had been built with transverse frames or "ribs" within their water-tight skins; and with wooden ribs this arrangement was probably the best that could be made. With an iron skin and ribs the case was very different: yet the old transverse arrangement of framing was imitated faithfully in the earlier iron ships, and still survives in by far the greater number of iron ships. Every one who has visited an iron ship yard and seen a ship "in frame" on the stocks, must have remarked the fact now mentioned. It should, however, be added that the continued use of transverse ribs in iron ships is rather a matter of convenience than of tradition: it does not most fully develope the capacities of iron as a constructive material, but it answers practical purposes well, even in the largest ships, and it much facilitates the work of building.

It is unnecessary to trace the history of iron ship building in any detail beyond the date of the *Great Britain's* construction. As the capabilities of the material have become better understood, and its manufacture has been developed, so have the sizes and speeds of iron ships been increased. The *Great Britain* sinks almost into insignificance when contrasted with the Atlantic steamers now at work, the largest of which are nearly 500 feet long, while their total weight is three times as great as that of their predecessor. But even these magnificent vessels appear small beside the *Great Eastern*, which is nearly 700 feet long, and exceeds 27,000 tons in weight when fully laden. Different opinions may be entertained as to the wisdom displayed by Mr. Brunel in planning such a monster ship, but there can be no difference of opinion as to the skill with which the structural arrangements were designed by Mr. Brunel, assisted by Mr. Scott Russell. The ship must always remain a monument of what can be done with iron in the association of lightness with strength, and although her design dates from 1852–3 it surpasses in simplicity and efficiency of construction nearly all the large mercantile steamers of the present day. The structures of our armoured ships have also been greatly influenced by the principles exemplified in the *Great Eastern;* and it is worthy of remark that the same system of construction, with some minor modifications, would be exceedingly well adapted for use in *steel* ships, should that material replace iron, as it appears likely to do.

Iron ship building has made its way in the face of much opposition and popular prejudice. Mr. Scott Russell relates an anecdote bearing on this matter, which will illustrate a feeling at one time very general, but now almost non-existent. "A good many years ago," he says, "I happened to converse with the chief naval architect of one of our dockyards on the subject of building ships of iron: the

answer was characteristic, and I have never forgotten it; he said with some indignation, 'Don't talk to me about iron ships; it's *contrary to nature.*'" The source of this popular error is obvious at a glance. Iron in the form of single plates or solid bars is so heavy that it cannot float; but if thin sheet iron and angle bars are used to make a box it will float readily enough, because it excludes water from a considerable space; and it is a fundamental law of hydrostatics that a floating body must "displace" a weight of water equal to its own weight. Those persons who objected to iron on the ground of its heaviness, omitted to notice the fact that many kinds of timber are, bulk for bulk, heavier than water, and so will not float any more than solid masses of iron. As a matter of fact, the hulls of iron ships are actually *lighter* than those of wood ships; so that of two vessels having the same outside form and draught of water, that built of iron would carry a considerably greater weight of cargo than the other built of wood. Experience shows that to give sufficient strength to a wooden hull it must be made nearly as heavy as the burden it carries; whereas, iron hulls often carry cargoes twice as heavy as themselves without showing the slightest signs of weakness. The gain in favour of the carrying power of iron ships is consequently about *one-sixth* of the total weight of a ship and her lading; and this is not only a most important commercial advantage, but it also helps to explain what perhaps may have required explanation—the disuse of wood in favour of iron.

INDUSTRIAL LEGISLATION.—III.

MR. HOBHOUSE'S BILL—OASTLER'S APPEAL.

By James Henderson, one of H.M. Assistant-Inspectors of Factories.

Although obtained after a very long and arduous struggle, the Factory Act of 1819 afforded such a small amount of relief to the oppressed and suffering factory children, that it did little to allay the agitation which the exposure of their wretched condition had provoked. The Act practically proved inoperative, as it contained no provision for compelling witnesses to attend and give evidence in the event of a prosecution, nor was there any special authority given to an executive officer to enforce this particular law. Several attempts were made to improve the Act, none of which, however, succeeded, until, in the year 1825, Mr. John Cam Hobhouse (afterwards Lord Broughton), then member for Westminster, introduced a Bill which aimed in the first instance at reducing the hours of work of children in cotton factories to eleven hours a day, and also at strengthening the authority of the magistrates whose duty it was to enforce it. When this measure was first introduced, several members of the House of Commons expressed their warm approval of it, and urged that it ought to be extended so as to embrace the children employed in all textile factories. On the second reading of the Bill, on the 16th of May, 1825, its rejection was moved by Mr. Hornby, the member for Preston, who maintained that if this additional restriction were to be imposed upon the cotton trade, the annual production would be curtailed to the extent of two millions and a half sterling. Mr. Hobhouse in his reply very appositely remarked that this was not a consideration, where the health, the comfort, and the happiness of so many children were concerned. Among the members who took part in the discussion on this occasion was Sir Francis Burdett, who contended that the helpless children in factories should not be sacrificed to the avarice and cupidity of their unfeeling parents, or of those by whom their labour was purchased. These parents, whatever their right might be to receive the profits of their children's labour, had no right to sell them. "We heard of slavery abroad," continued Sir Francis, "but, good God! did we ever hear of any such instances of over-working as had been published with respect to the labour of children in the cotton manufactories? These wretched little beings were in many instances employed day after day for more than twelve hours at a time. Why, had any man a horse that he could think of putting to such toil? It was shocking to humanity; and it was still more odious when it was considered that these children, if they chanced to be overpowered by sleep, were beaten by the spinners until they awoke." Moderate as Mr. Hobhouse's proposals were, he found it

impracticable to carry them, in the teeth of the powerful opposition which was offered in the House of Commons to any farther limitation of hours of work in cotton factories. On the 31st of March, therefore, when the House went into committee on the Bill, Mr. Hobhouse was constrained to withdraw his proposal to restrict the hours of work to eleven per day, and to substitute for it one which sanctioned twelve hours' work on the first five days of the week, and nine hours on Saturday, making a total of sixty-nine hours a week for a child of nine years of age. This was a reduction of three hours a week, as compared with the limit fixed by Sir Robert Peel's Act of 1819; but the main object which Mr. Hobhouse had in view, was to render that Act really operative, by giving magistrates power to compel the attendance of witnesses. This he secured, although he had to abandon the suggestion to reduce the hours of work to sixty-six in the week.

At this distance of time, and with the additional knowledge and experience which we have acquired as to the most suitable conditions under which factory labour can be really successfully prosecuted, the persistent opposition offered to such moderate measures as that proposed in 1825 by Mr. Hobhouse can hardly fail to surprise and astonish us. Much of this was due undoubtedly to sheer ignorance of the consequences on the part of the general public. And this ignorance is not surprising, when we bear in mind the character of some of the medical and professional evidence which was given before the several committees who inquired into this question, prior to the passing of the Act of 1819. Mr. Hobhouse made some allusion to this when moving the second reading of his Bill of 1825. The opinion of some medical gentlemen was relied upon as a proof that seventy-two hours' labour a week was not too much for a child of nine years; but the weight which was to be attached to such an opinion might be judged of from the fact that one of the medical witnesses examined against the Bill, when asked whether a child could keep standing at its work for twenty-three hours continuously without injury to its health, replied that the question was one of great doubt. Another medical witness denied that the inhaling of cotton dust and fly was injurious to health, and on being asked to explain why, answered that the effects were counteracted by constant expectoration. "And is not constant expectoration injurious to health?" asked another member of the committee. "That," replied the witness, "depends upon a variety of facts."

Special pleading of this kind, however, availed little against the growing conviction throughout the country that a more efficient check should be placed upon the abuses which, it was clearly established, prevailed in respect to the employment of children and young persons in the textile factories of the United Kingdom. Sir Robert Peel's Act of 1819 had effected a partial improvement; but it was no more than partial. The more humane and considerate among the cotton manufacturers frankly accepted it, and obeyed it, but it was notorious that by others it was shamelessly and openly violated. Unfortunately, the machinery for enforcing the law against such wilful offenders was wholly inadequate. But the men who had taken the amelioration of the factory children in hand were not easily discouraged, and they persevered in their noble work. It has been estimated that Mr. Nathaniel Gould, of Manchester, expended on his own account some £15,000 on the agitation which preceded the passing of the Act of 1819. The debates on Mr. Hobhouse's Bill, in the session of 1825, gave a fresh impetus to the agitation of this question of factory legislation in the cotton manufacturing districts, more especially in Lancashire. Short time committees were established in the chief towns, such as Manchester, Stockport, Bolton, and Blackburn. Among those who took an active share in this work of organisation was Mr. Philip Grant, of Manchester, who subsequently published a history of the agitation for a ten-hours' Factory Bill which has had an extensive circulation. Among the factory operatives who were associated with him on the Manchester committee, after the passing of Mr. Hobhouse's Act, in 1825, he mentions the names of Thomas Foster, John Doherty, James Turner, and Thomas Daniel. It was not alone the opposition of certain of the factory owners that these men had at this time to contend against, for Mr. Grant acknowledges that among the workpeople themselves the proposal to limit the hours of work of the children employed was unpopular. As in the case of the introduction of improved machinery, the effect apprehended from this movement was, that it would interfere with their employment and reduce their earnings.

It was about this time that the whole nation was engrossed in the interesting and absorbing question of colonial slavery. In the manufacturing districts of the North of England, and especially in Yorkshire, the subject was debated with an earnestness

and an enthusiasm seldom witnessed. The West Riding rang with the eloquent denunciations of social oppression, so forcibly expressed by Lord Brougham, and a timely and powerful appeal on behalf of the factory children was made at this juncture by a gentleman who was ultimately induced to become one of the most prominent leaders in the movement for their emancipation and protection—namely, Mr. Richard Oastler, who in subsequent years came to be known among the factory operatives by the familiar *soubriquet* of "The Factory King." Mr. Oastler resided at Fixly Hall, near Huddersfield, and as a matter of course was familiar with the social changes which were being rapidly effected around him by the wonderful development and extension of the woollen and worsted manufactures. Step by step, but somewhat later in the day, these branches of manufacturing industry were, like the cotton manufacture, being altogether revolutionised by the introduction of steam power and improved machinery. The increase in the productive power, great as it was, failed to keep pace with the demand for the manufactured goods, and new mills and factories were rapidly erected in every populous centre. The processes of the manufacture, particularly in the worsted trade, admitted of the employment of young children in large numbers with advantage, and very soon they were to be found at work in thousands. At this time, it is to be borne in mind, no law existed which in any way regulated the employment of children either in a woollen or a worsted mill. The application of the Factory Acts, which had been obtained after so much trouble and agitation, was limited solely to cotton factories; and if even under their protective influence such abuses could exist as had been established in the case of cotton factories, our readers may safely conclude that the state of matters was certainly no better when children were employed in large numbers in the woollen and worsted manufactures.

It was at this juncture that Mr. Richard Oastler appeared on the field; and in October, 1830, a letter with his signature attached was published in the *Leeds Mercury*, which exercised a most remarkable influence upon the sentiments and opinions of the public upon this question. The document, indeed, has an historical value, as it indicates an entirely new and important departure in the public agitation for factory legislation. We think it important, therefore, to append it *in extenso* as it appeared in the *Leeds Mercury*. It was as follows:—

YORKSHIRE SLAVERY.

To the Editors of the "Leeds Mercury."

"It is the pride of Britain that a slave cannot exist on her soil; and if I read the genius of her constitution aright, I find that slavery is most abhorrent to it—that the air which Britons breathe is free—the ground on which they tread is sacred to liberty."—*Rev. R. W. Hamilton's Speech at the Meeting held in the Cloth Hall Yard, Sept. 22nd*, 1830.

Gentlemen,—No heart responded with truer accents to the sounds of liberty which were heard in the Leeds Cloth Hall Yard on the 22nd inst. than did mine; and from none could more sincere and earnest prayers arise to the throne of Heaven, that hereafter slavery might only be known to Britain in the pages of her history. One shade alone obscured my pleasure, arising not from any difference in principle, but from the want of application of the general principle to the whole empire. The pious and able champions of negro liberty and colonial rights should, if I mistake not, have gone farther than they did; or, perhaps, to speak more correctly, before they had travelled so far as the West Indies should at least for a few moments have sojourned in our own immediate neighbourhood, and have directed the attention of the meeting to scenes of misery, acts of oppression, and victims of slavery, even on the threshold of our homes.

Let truth speak out, appalling as the statement may appear. The fact is true. Thousands of our fellow-creatures and fellow-subjects, both male and female, the miserable inhabitants of a Yorkshire town (Yorkshire, now represented in Parliament by the giant of Anti-Slavery principles) are at this very moment existing in a state of slavery, more horrid than are the victims of that hellish system, "colonial slavery." These innocent creatures drawl out unpitied their short but miserable existence in a place famed for its profession of religious zeal, whose inhabitants are ever foremost in professing "temperance," and "reformation," and are striving to outrun their neighbours in missionary exertions, and would fain send the Bible to the farthest corner of the globe—ay, in the very place where the anti-slavery fever rages most furiously, her apparent charity is not more admired on earth than her real cruelty is abhorred in heaven. The very streets which receive the droppings of an Anti-Slavery Society are every morning wet by the tears of innocent victims at the accursed shrine of avarice, who are compelled, not by the cruel whip of the negro slave driver, but by the dread of the equally appalling thong or strap of the overlooker, to hasten, half-dressed, but not half-fed, to those magazines of British infantile slavery—the worsted mills in the town and neighbourhood of Bradford!!!

Would that I had a Brougham's eloquence, that I might rouse the hearts of the nation, and make every Briton swear "These innocents shall be free!"

Thousands of little children—both male and female, but principally female—from seven to fourteen years of age, are daily compelled to labour from six o'clock in the morning till seven in the evening, with only—Britons! blush while you read it—with only thirty minutes allowed for eating and recreation. Poor infants! ye are indeed sacrificed at the shrine of avarice, without even the solace of the negro slave; ye are, no more than he is, free agents; ye are compelled to work as long as the necessity of your needy parents may require, or the cold-blooded avarice of your worse than barbarian masters may demand! ye live in the boasted land of freedom, and feel, and mourn that ye are slaves, and slaves without the only comfort

which the negro has. He knows that it is his sordid, mercenary master's interest that he should live—be strong and healthy; not so with you. You are doomed to labour from morning to night for one who cares not how soon your weak and tender frames are stretched to breaking!

You are not mercifully valued at so much per head! this would assure you at least, even with the worst and most cruel masters, of the mercy shown to their own labouring beasts. No, no! your soft and delicate limbs are tired, and fagged, and jaded, at only so much per week; and when your joints can act no longer, your emaciated frames are cast aside, the boards on which you lately toiled and wasted life away are instantly supplied with other victims, who, in this boasted land of liberty, are hired—not sold—as slaves, and daily forced to hear that they are free. Oh, Duncombe! thou hatest slavery—I know thou dost resolve that Yorkshire children shall no more be slaves. And Morpeth! who justly glories in the Christian faith. Oh, Morpeth! listen to the cries and count the tears of these poor babes, and let St. Stephen's hear thee swear they shall no longer groan in slavery! And Bethel, too! who swear'st eternal hatred to the name of slave, whene'er thy manly voice is heard in Britain's senate, assert the rights and liberty of Yorkshire youths. And Brougham! thou who art the chosen champion of liberty in every clime, oh, bend thy giant's mind and listen to the sorrowing accents of these poor Yorkshire little ones, and note their tears; then let thy voice rehearse their woes, and touch the chord thou only holdest—the chord that sounds above the silvery notes in place of heavenly liberty, and, down descending at thy will, groans in horrid caverns of the deep, in muttering sounds of misery accursed to hellish bondage; and as thou soundest these notes, let Yorkshire swear, "Here children shall be free!" Yes, all ye four protectors of our rights, chosen by freemen to destroy Oppression's rod—

> Vow one by one, vow altogether, vow,
> With heart and voice eternal enmity
> Against oppression by your brethren's hands,
> Till man, nor woman, under Britain's laws,
> Nor son, nor daughter, born within her empire,
> Shall buy, or sell, or hire, or be a slave.

The nation is now most resolutely determined that negroes shall be free. Let them, however, not forget that Britons should have common rights with Afric's sons.

The blacks may be fairly compared to beasts of burden kept for their master's use; the whites to those which others keep and let for hire. If I have succeeded in calling the attention of your readers to the horrid and abominable system on which the worsted mills in and near Bradford are conducted, I have done some good. Why should not children working in them be protected by legislative enactments, as well as those who work in cotton mills? Christians should feel and act for those Christ so eminently loved, and declared that "of such is the Kingdom of Heaven."

I remain, yours, &c.,

Richard Oastler.

Fixly Hall, near Huddersfield,
September 29, 1830.

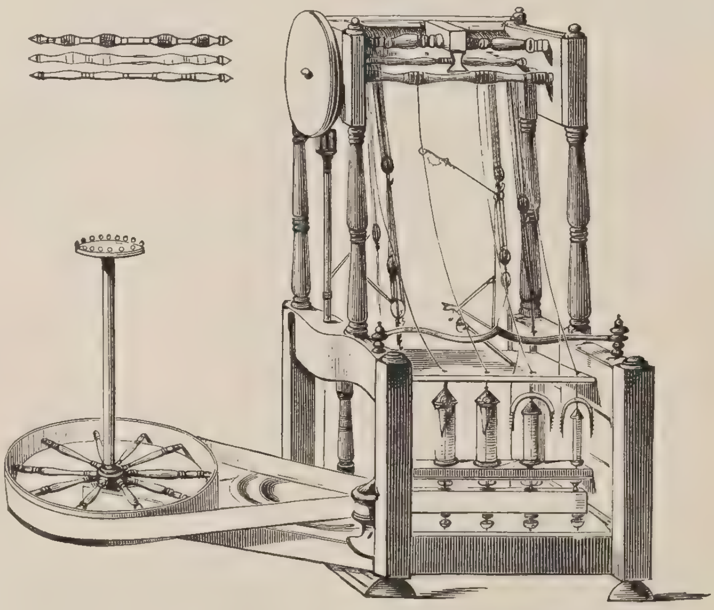
COTTON.—IV.

THE STORY OF ARKWRIGHT'S LIFE (*continued*)—THE INVENTIONS OF THOMAS HIGHS.

By David Bremner, Author of "The Industries of Scotland."

MANY obstacles, as we have seen, were thrown in Arkwright's way in working out his ideas and laying the foundation of the factory system. His mill at Cromford was an object of much aversion to the manufacturers of Lancashire; and when the powers of the machinery he had devised for it became known, no pains were spared to crush the inventor. In drawing up his specifications, Arkwright left several loopholes, which enabled his opponents to dispute his patent rights successfully on two occasions. "The most extraordinary piece of malevolence," says Dr. Ure (one of the most friendly of Arkwright's biographers), in his "History of the Factory System," "which, if not well attested, would be incredible, was the manufacturers of Lancashire combining not to buy Arkwright's yarn, though it was acknowledged to be superior in quality to any in the market." His best servants were bribed to leave his employment, and a mill which he had built at Birkacre was burned by incendiaries, acting, it was alleged, under the instructions of the disaffected cotton manufacturers of the district. After the first trial of his patent, in 1781, which resulted in its being set aside on the ground of obscurity and defectiveness in the specification, Arkwright published his "Case," in which his object was to set himself right in the eyes of the unprejudiced public. An extract from that document will show the spirit of the time with which the inventor had to contend:—"No sooner were the merits of Mr. Arkwright's invention fully understood, from the great increase of material produced in a given time, and the superior quality of the goods manufactured; no sooner was it known that his assiduity and great mechanical abilities were rewarded with success, than the very men who had before treated him with contempt and derision began to devise means to rob him of his inventions, and profit by his ingenuity. Every attempt that cunning could suggest for this purpose was made, by the seduction of his servants and workmen (whom he had with great labour taught

the business). A knowledge of his machinery and inventions was fully gained. From that time many persons began to pilfer something from him; and then by adding something else of their own, and by calling similar productions and machines by other names, they hoped to screen themselves from punishment. So many of those artful and designing individuals had, at length, infringed on his patent right, that he found it necessary to prosecute several; but it was not without great difficulty and considerable expense that he was able to make any proof against them; conscious that their conduct was unjustifiable, their proceedings were conducted with the utmost caution and secrecy. Many of the persons employed by them were sworn to secrecy, and their buildings and workshops were locked up or otherwise secured. This necessary proceeding of Mr. Arkwright occasioned, as in the case of poor Hargreaves, an association against him of the very persons whom he had served and obliged. Formidable, however, as it was, Mr. Arkwright persevered, trusting that he should obtain, in the event, that satisfaction to which he appeared to be justly entitled. A trial in Westminster Hall, in July last [1781], at a large expense, was the consequence; when, solely by not describing so fully and accurately the nature of his last complex machinery, as was strictly by law required, a verdict was found against him." At that time the capital invested in factories in which Arkwright's machinery was used was £200,000, and the number of persons employed was 5,000. The result of this adverse verdict induced Arkwright to abandon eight other actions which he had entered against persons who infringed what he believed to be his rights, and to forego, for a time, at least, the advantages which he hoped he had secured by his second patent. By the beginning of the year 1785 he had, however, obtained such a weight of testimony by competent persons to the justice of his claims, and the sufficiency of his specification, that he was led to take fresh proceedings to secure the fruits of his ingenuity and enterprise. A trial in February of the year mentioned resulted in a verdict in his favour, and once more his monopoly was secured to him.

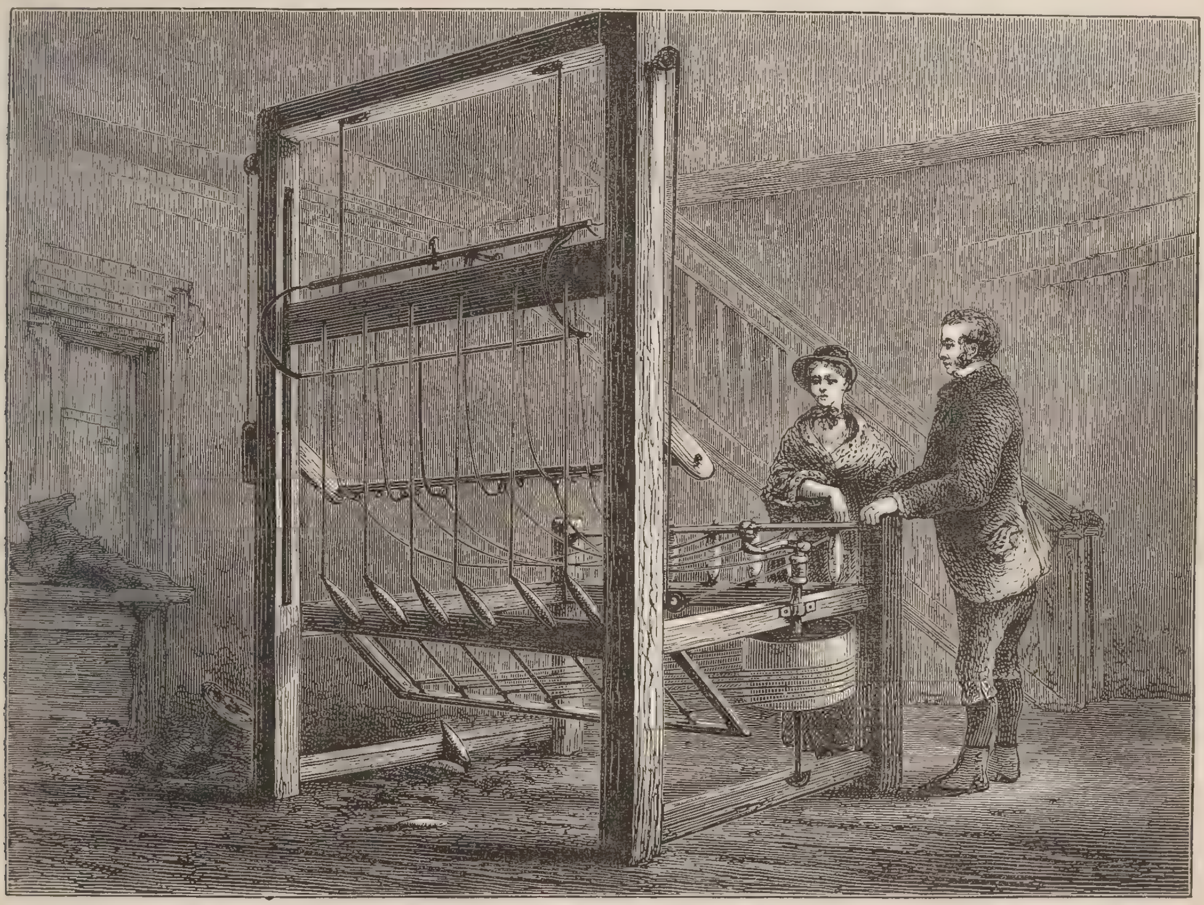


ARKWRIGHT'S WATER-FRAME SPINNING MACHINE. (*Specification Drawing.*)

He was not destined to enjoy it long, however, for immediately after the favourable verdict was passed, the cotton spinners of Lancashire applied for and obtained a writ of *scire facias* to try the validity of the patent. The trial took place in June of the same year, and excited much interest. Counsel for the Crown opposed the patent on four grounds—1st, that it was a great inconvenience to the public; 2nd, that it was not a new invention at the time of the patent being granted; 3rd, that it was not a new invention by Mr. Arkwright at all; and 4th, that he had not disclosed his invention in the specification. Evidence was led to show that several of the improvements in the carding machine claimed by Arkwright were the invention of other persons, and also that spinning by means of rollers had been practised long before Arkwright came upon the scene as an inventor or adapter of cotton machinery. The case against Arkwright was undoubtedly strong, and his defence was weak. The consequence was, that the jury without a moment's hesitation returned a verdict for the Crown, thus annulling the patent and destroying Arkwright's monopoly. The machines thus made available for general use were readily and extensively adopted, the result being a great expansion of the cotton manufacture of the country. By that time Arkwright's material position was secured, however; and, though deprived of the power to charge royalties for the use of his machines, he was able, by applying himself to the development of the factories he had built for himself, to achieve a position of affluence. His competitors failed for a considerable time to equal the quality of the yarns he produced, and he consequently

held a strong position in the markets. His three sons were engaged in the business, and relieved him in his later years from the exertion of active superintendence—a relief which must have been grateful to one who had led such a busy life, and who had had to fight the prejudices and jealousies of a powerful combination of capitalists.

Some incidents of Arkwright's domestic life have already been mentioned. He was twice married, his first wife being Patience Holt, of Bolton, who died in 1761, and whose existence is barely noticed by his biographers. Of his second wife, Margaret Biggins, of Pennington, in the parish of Leigh, almost the only thing recorded is, that she refused to sanction the sale of some property which belonged to her in her own right, in order that her husband might with the money develop some of his ideas on cotton spinning. Some unpleasantness arose out of the refusal, and a separation took place. Arkwright was a man of most industrious habits, and a strict economiser of time. When fifty years of age, he made attempts to overcome the deficiencies of his early education, and from the time usually allotted to sleep he dedicated one hour a day to the study of grammar, and another hour to writing and orthography. Having taken up his abode in Derbyshire, he interested himself in the affairs of the county, and in 1786 had the honour of being elected High Sheriff. In that capacity it fell to his lot to present an address to his Majesty George III., congratulating him on his escape from the attempt made on his life by Margaret Nicholson, and on that occasion he was knighted by the king. The malady from which he suffered during the greater part of his existence became complicated with other derangements of the system, and Sir Richard Arkwright's busy and useful life closed in the year 1792, he being then in his sixtieth year. To his heirs he left, besides his mills, a fortune of about £500,000, and to his country a legacy the value of which can never be reckoned. His son Richard, who inherited much of his father's sagacity and aptitude for business, was so successful in his undertakings that he was reckoned to be the wealthiest commoner in England. He died in 1843, in the eighty-eighth year of his age, leaving a large family. In proving his will, the personalty was sworn to exceed one million sterling,



HIGHS' SPINNING-JENNY.

that being, however, a nominal sum, because the scale of stamp duty went no higher. The probate bore a stamp of £15,700.

Though Arkwright did much for the cotton trade, and achieved a position of affluence for himself, there can be no doubt that the unfavourable criticisms of some of his biographers had some foundation. The fairest estimation of the man is, perhaps, that given by Mr. Baines, in his "History of the Cotton Manufacture," which is as follows:—"I have found myself compelled to form a lower estimate of the inventive talents of Arkwright than most previous writers. In the investigation I have prosecuted I have been guided solely by a desire to ascertain the exact truth. It has been shown that the splendid inventions, which even to the present day are ascribed to Arkwright by some of the ablest and best-informed persons in the kingdom, belong in great part to other and much less fortunate men. In appropriating those inventions as his own, and claiming them as the fruits of his unaided genius, he acted dishonourably, and left a stain upon his character, which the acknowledged brilliance of his talents cannot efface. Had he been content to claim the merit which really belonged to him, his reputation would still have been high, and his wealth would not have been diminished. That he possessed inventive talent of a very superior order has been satisfactorily established; and in improving and perfecting mechanical inventions, in exactly adapting them to the purposes for which they were intended, in arranging a comprehensive system of manufacturing, and in conducting vast and complicated concerns, he displayed a bold and fertile mind and consummate judgment; which, when his want of education and the influence of an employment so extremely unfavourable to mental expansion as that of his previous life are considered, must have excited the astonishment of mankind."

For the sake of enabling a comparison to be made between the processes carried on in Arkwright's mills with those which may be witnessed in factories containing machinery of the latest device, to be described farther on, we give here an extract from a description of the treatment of cotton in one of Arkwright's mills at Cromford, which was written by Mr. Strutt for "The Beauties of England and Wales," published in 1802:—"When the cotton is sufficiently picked and cleaned (an operation that furnishes employment to a great number of women), it is carefully spread upon a cloth, in which it is afterwards rolled up in order to be carded. To the carding machine belong two cylinders of different diameters, the larger of which is covered with cards of fine wire, and over, and in contact with it, are fixed a number of stationary cards, that, in conjunction with the revolving cylinders, perform the operation of carding. The smaller cylinder is encompassed by fillet cards, fixed in a spiral form, and is also provided with an ingenious piece of machinery called a crank. The roll of cloth before mentioned, being applied to the machine, is made to unroll very slowly by means of rollers, so that it may continually feed the larger cylinder with its contents. When carded, the cotton passes from this to the smaller cylinder, which revolves in contact with the other, and is thence stripped off by the motion of the crank, not in short lengths, but in continuation, and having the appearance of a very thin fleece, which, if not intended to pass a second time through the carding machine, is immediately contracted by passing betwixt a pair of rollers into what is called a *row* or length. The next part of the process is that of sizing. The machine by which this is performed has two pairs of rollers, that are placed at a proper distance from each other, and revolve with different velocities, arising either from the variation of size in the pairs of rollers, from their performing a different number of revolutions in the same space of time, or from both these causes united. When the lengths of cotton are brought from the carding machine, several of them together are applied to the rollers now mentioned, and the effect produced is not only that the lengths thus applied in conjunction coalesce and come out single, but also that the fibres of the cotton are drawn out longitudinally by the different velocities and pressure of the rollers; hence the cotton is now termed a *drawing*. This process is several times repeated, and several drawings are each time united by passing together betwixt the rollers, the number introduced being so varied that the last drawing may be of a size proportioned to the fineness of the thread into which it is intended to be spun. The cotton is now in a fit state for roving. This operation is performed by passing the last-mentioned drawing between two pairs of rollers, which revolve with different velocities, as in the former machine. It is then received into a round conical can revolving with considerable swiftness. This gives the drawing a slight twisting, and prepares it for winding, which is done by hand, upon large bobbins by the smaller children. When in this state, the cotton is applied to the spinning machine. Here it is passed between pairs of rollers, which, revolving with various degrees of velocity, draw it out, and reduce

it to a proper degree of tenuity, at the same time it is sufficiently twisted by the revolving of spindles, upon which bobbins are placed; and the yarn thus twisted is caused to wind on the bobbins by the friction of their ends upon laths placed horizontally. These laths have another very essential office to perform, which is that of raising and falling the bobbins so that the yarn may be spread over their whole length, otherwise the thread would require to be moved very frequently, as is the case in the common spring wheel. When thus wound upon bobbins, the cotton is ready for use."

At the three mills which Arkwright built in Derbyshire, 1,150 persons were employed—namely, 150 men, 300 women, and 700 children. The establishments seem to have been models in every respect. The authority just quoted says of them:—"Proper attention is paid to the health and morals of the children, who are not admitted into the mills till they have been some time at school; and Sunday-schools are supported by Mr. Arkwright [son of Sir Richard] for their instruction afterward. The mills are not worked by night, and are constantly kept very clean and neat." It was one of these mills that inspired the muse of Dr. Darwin to produce the description of cotton spinning which appears in "The Botanic Garden:"—

"——Where Derwent guides his dusky floods,
Through vaulted mountains and a night of woods,
The nymph *Gossypia* treads the velvet sod,
And warms with rosy smiles the wat'ry god:
His pond'rous oars to slender spindles turns,
And pours o'er massy wheels his foaming urns;
With playful charms her hoary lover wins,
And wheels his trident while the monarch spins.
First, with nice eye emerging naiads cull
From leathery pods the vegetable wool;
With wiry teeth *revolving cards* release
The tangled knots and smooth the ravell'd fleece;
Next moves the *iron hand* with fingers fine,
Combs the wide card, and forms th'eternal line;
Slow with soft lips the *whirling can* acquires
The tender skeins, and wraps in rising spires;
With quicken'd pace *successive rollers* move,
And these retain, and those extend the *rove.*
Then fly the spokes, the rapid axles glow,
While slowly circumvolves the lab'ring wheel below."

One of the witnesses brought forward against Arkwright at the trial of his patent was Thomas Highs, of Leigh, a man of undoubted mechanical genius. He claimed to be the inventor of the system of spinning by rollers which Arkwright had adopted and patented as his own; and professed that his machine had been made for him by Kay, of Warrington, in the year 1767, two years before the date of Arkwright's first patent. Mr. Guest, in his "Compendious History of the Cotton Manufacture," takes up Highs' case, and attributes to him the authorship of the most important parts of the machinery used in working cotton. He even gives him credit for having anticipated Hargreaves with the spinning-jenny, and his book contains an engraving of the machine. The arrangement of its parts differed considerably from Hargreaves' invention, the framework being perpendicular instead of horizontal. The spindles were arranged in the lower part, and the clasps which held the roving while being elongated were made to travel in grooves cut in the sides of two upright posts. Its mode of operation was this:—The clasp having been let down near to the spindles, a portion of roving sufficient for one draw was let out. The spindles were then set in motion, and by pulling a cord the clasps were drawn upward, and the spinning effected. In a general way the machine might be described as Hargreaves' jenny set up on end; but the latter was a much more perfect machine. Indeed, Highs' jenny appears to have been but a crude development of a valuable idea. This much is certain about Highs, however, that in the year 1771 he devised what was called a double jenny. The machine had twenty-eight spindles on each side, which were turned by a drum or roller placed in the centre. It was publicly exhibited in the Manchester Exchange in 1772, and was so easily managed that it was worked by a son of the maker ten years of age. So highly was the machine thought of that the manufacturers of the town subscribed a fund of £200, which was presented to Highs for his ingenuity. In the disputes which arose as to the originators of the various parts of cotton-preparing and spinning machinery, it seems beyond doubt that there was a good deal of hard swearing, and that some of the claims put forward were utterly without foundation. The life of an inventor is usually one of strange vicissitudes, and it is reasonable to suppose that the rewards did not always fall into the right hands.

IRON AND STEEL.—V.

CASTINGS.

By William Dundas Scott-Moncrieff, C.E.

IN the last paper, we gave an historical account of the various improvements which have been adopted for producing castings, and concluded with a short description of the apparatus employed in a foundry. Before describing the different kinds of castings, and the uses to which they are put, it may be well that the reader should clearly understand the difference between cast and malleable iron constructively—that is, in their relation to structures. When dealing with the Blast Furnace, it was explained that the change which takes place when pig iron is converted into wrought iron arises from the carbon being extracted from it; and among the peculiarities which follow from this process, we pointed out that one of the most prominent was the alteration in the temperature of the melting-point of the two materials. This was illustrated by the case of a blacksmith's forge, which is only capable of producing a welding-heat in malleable iron, but which would reduce cast iron to a fluid condition, if the heat were continuously applied. The most important difference in practice, however, is that of the great capability of cast iron for resisting crushing strains, or compressive strength; and the capacity of wrought iron to resist strains in an opposite direction, or *tensile* strength. Every structure, whether it be a house or a steam engine, depends for its stability and safety upon the manner in which the materials composing it are disposed in order to resist these forces; and the foundations of the sciences of engineering and architecture may be said to rest upon a knowledge of how to resist them with the least expense of material and labour.

Any one who was ignorant of the difference that exists between cast and wrought iron, and who reversed the materials employed in the construction of a steam engine, would find that the boiler, in the first place, would fly to pieces, and that if the engine itself were set in motion it would immediately follow. These facts must have been discovered by experience in a very remote period of the manufacture of iron; but it may be interesting to the reader to know something of the experiments that were made more recently, upon which the rules for disposing materials to their proper place in every structure depend. The most prominent authority upon this subject is the late Sir William Fairbairn, who made a series of experiments extending over many years, along with Professor Hodgkinson, at the request of the British Association. We will only refer to those that bear upon Castings. In the first place, to show the tensile strength of cast iron, which is very much less —about one-fourth—than that of wrought iron, a casting was made of a cruciform transverse section, very strong and solid at each end, so as to admit of a large ring being passed through for attaching it to the apparatus used for testing its strength. The larger castings were broken by the chain-testing machine belonging to the Corporation of Liverpool, and the smaller ones by means of levers. The result of these experiments showed that the tensile strength of good cast iron varies from 6 tons to 8 tons per square inch—that is to say, a bar of cast iron one inch square in section, if it were secured at one end to a wall, and at the other to a weight passing over a pulley, would break when the strain on the bar reached 6 to 8 tons. From this it will be seen how unsuitable a material cast iron would be to make into chains, or any sort of appliance which requires to resist a tensile strain. When we come to the experiments that were made to show its resistance to compression, however, we find that the advantage is all on the side of cast iron. In building a house, it is merely a question of height whether the materials forming the foundations will remain solid, or be crushed to powder by the weight of the super incumbent mass; but if the material of which the house was built were blocks of cast iron, these experiments prove that there is practically no limit to the height to which you might build it, as many miles would be within the limit of safety, so far as the crushing of the materials went. In order to discover what the strength of cast iron is to resist compression, small cylinders were placed between parallel steel discs, which were crushed together by means of levers, and it was found that the resistance varied from 81,770 lb. per square inch to 145,435 lb. per square inch—that is, from about 36 to 64 tons; while wrought iron could only stand a pressure of 8 tons; though any comparison between the two is really not reliable, as the tendency of the wrought iron to crumple up increased, of course, very greatly with the length or thinness of the material that was tested. The results of a vast number of experiments made upon different kinds

of cast iron proved that the advantage lay with the pigs made from the old cold-blast process, in the following particulars: direct tensile strength, compressive strength, transverse strength, power to resist impact, stiffness, and specific gravity; whilst the only advantage on the side of the hot blast is, that it bends somewhat farther than the cold blast before breaking. As cast iron, however, is generally required to bear strains that, to be safe at all, ought to be far within the limit of its strength, any little difference that may exist between hot and cold-blast pigs is of no practical importance. There are hardly any points that can be raised upon the different kinds of strains to which iron is subjected that have not been fully experimented upon by Sir William Fairbairn; and among these is the strength to resist twisting or *torsion*. Of course, some sort of standard had to be fixed upon, as in the case of pounds on the square inch, with which different kinds of iron were compared in the previous experiments; and so an angle was taken of half a degree through which the iron was twisted, so as to give it a permanent "set," and it was found that just about half the strain was necessary in the case of malleable iron that was required in castings, and that much less was needed in the case of bronze. It had long been known that when iron has been repeatedly melted it alters its character; but Sir William Fairbairn discovered that its greatest strength and elasticity were reached only at the twelfth melting, and that its resistance to compression went on increasing to the eighteenth melting, when it reached 88 tons on the square inch. As cast iron is constantly returning to foundries in the form of "scrap," it is of importance to know how it is affected by repeated meltings; and these experiments showed that when the iron has been passed through the furnace more than twelve times it becomes unsuitable for most of the purposes for which it is usually employed.

Although nothing may appear to be more solid than the great iron bridges which span our rivers or ravines, and bear the weight of passing trains and the traffic of our great cities, it was discovered long ago that vibration had a very material effect upon the strength of these structures, and they had to be made much stronger upon this account. It was also found by experience, that changes in the amount of the load, as in bridges that are crossed by railway traffic, had the effect of weakening the structure, so that what appeared to be amply strong enough at first would become dangerous in the course of a few years. Upon examining iron that has been subjected to repeated vibration, it is found that it has become altered in its character, and that tough, fibrous wrought iron becomes crystalline and brittle when repeatedly hammered at a low temperature. This is partly attributed to changes in its magnetic condition, and some scientific men believe that it is wholly to be attributed to this cause; but whether this is the case or not, the effect of percussion and change of load is so great that it requires to be taken into account in all structures, whether they are made of wrought iron or castings. The breaking of axles of railway carriages is very often accounted for in this way, and the Commission upon Railway Structures tried to settle the question by direct experiment, when it was found that no casting (in the form of a bar) was able to withstand more than 4,000 blows, each of which was sufficient to bend the bar half-way to the point at which it would break by dead pressure, but that all the bars resisted the same number of blows when they only deflected the bar one-third of the way to the point of fracture. In order to discover the effect of changes of load upon other kinds of beams, there was a very well-known experiment made upon one constructed as shown in the sketch (Fig. 1)—

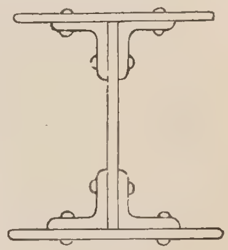


Fig. 1.

Depth of beam	16 inches.
Weight	7 cwt. 3 qrs.
Calculated breaking-weight . .	12 tons.
Distance between supports . .	20 feet.

One million changes of load were made, with weights varying from $\frac{1}{4}$th to $\frac{2}{5}$ths of the load that would break it. In the first series of experiments, which extended from the 26th of March to the 26th of July ensuing, the experiments were continuous till it broke; and the second series of experiments on the same beam after being repaired, sustained 3,000,000 additional changes, with a reasonable load when it broke."* This shows how careful engineers should be to make full allowance in their calculations for the deterioration in the strength of beams and bridges by the constant passage of heavy traffic.

We will now attempt to convey some idea of the place which castings take in the construction of machinery; and as this depends entirely upon its relation to wrought iron, in the matter of these different strains, we trust the explanations already given will help to make the subject more readily

Sir William Fairbairn's "Iron Manufacture," p. 248.

understood. In all machinery—in a steam engine, for instance—there are some parts that are stationary and others that are in motion. Now, as most of the moving parts are subjected to tensile strains, or twisting strains, and as wrought iron is much stronger than castings in these respects, the moving parts are generally made of malleable iron; and in nearly every case where the moving part is made of cast iron, as in a revolving spur wheel, the metal has to be disposed so as to take as much advantage as possible of its compressive strength or capacity for resisting crushing. The stationary parts, on the other hand, are generally subjected to strains of compression, or are so situated that additional weight, which is a drawback in moving parts, is not so much to be avoided, and can be conveniently added to resist any tensile strains that may exist, at the same time giving greater stability to the structure. This, then, is the general guide for disposing the different materials to their various duties: castings for compressive strains, wrought iron for tensile strains, and brass where there is any doubt of a casting being too complicated to be sound. In the old experiments made in the Baptist Mills at Bristol by John Darby, there were a great many difficulties found in substituting iron for brass, and these still exist so far that the more elaborate forms of moulds, especially when the metal requires to be thin, are generally filled with brass instead of iron, as the latter is very apt to run so as to form flaws that render the casting useless. In foundries that make a specialty of light castings, the pig iron is mixed in such a way that sound castings can be produced which would astonish the early pioneers of the industry; but in ordinary work, brass has a great advantage over iron in the soundness and toughness of the casting when it is thin or complicated.

When the drawings of a piece of machinery have been fully made out, it will be understood now that one part of them will require to be carried out with wrought and the other with cast iron; some details being taken to the forge, or smithy; others referring to the foundry; and others to the erecting shop, where the whole has to be put together. None of them, however, require to go to the foundry, because the first process in producing a casting is to make a "pattern," from which it is modelled, and this makes the moulder independent of a drawing. The foundry itself is made up of buildings that are high enough in the roof to admit of the introduction of large cranes for carrying heavy weights from one part to another. Outside, at a convenient distance—very often close to the exterior wall, through which there is a hole to admit of the molten metal being taken off from the interior—there are one or more cupola furnaces, where the iron is melted. The floor consists of a considerable depth of sand. The very finest qualities only are employed, and there is a considerable trade at several points on the sea coast where it is found in sufficient quantities and of sufficient fineness to admit of its being exported or conveyed to industrial centres where it is in large demand. There is one part of the coast of Aberdeenshire which is famous for this commodity, and the castings that are made from it are well known for the smoothness of their surface and the excellence of their finish. This sand, although it is beautifully white, yellow, or pink when it reaches the foundry, is soon so impregnated with charcoal that it becomes quite black. There is no grimier interior in any industry than that of a foundry—not even a coal pit. The castings which are made from moulds formed from this material are called "green-sand" castings, as opposed to "dry-sand" or "loam" castings, to which we shall presently refer. The making of the patterns from which the castings are moulded is a department of itself in every engineering establishment, and is superintended by a foreman who has had a special training. In the simpler forms the pattern is an exact fac-simile of the casting which is taken from it, except that a small allowance is made for the shrinking of the molten iron when it cools, so that the pattern is really a little larger. As this allowance is not more than $\frac{1}{10}$th of an inch to the foot, it makes no difference in its appearance. We will now take a small cylinder that has to be reproduced in solid cast iron, and show how it is produced. The principal part of the plant of a foundry over and above the cranes and ladles by which the molten metal is conveyed, consists of "boxes." These are made of cast iron, and are of a great variety of shapes and sizes, in order to meet the necessity of providing for the infinite variety of the castings which are moulded in them. Each of these boxes consists of an upper and lower half, and they are crossed with webs or thin plates of cast iron, to which the sand adheres by friction, so that it does not fall down when the box is in a perpendicular position. The lower half of the box is first laid upon the sandy bottom of the foundry, and after being partially filled with sand, the pattern is placed in it and packed all round, leaving the upper half exposed. The sand is then smoothed

over to the centre line, and a little "parting sand," which is fine, sharp, and perfectly dry, sprinkled over the surface, so as to prevent the

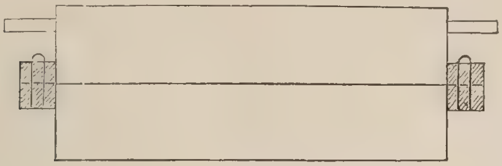


Fig. 2.

sand of the upper box adhering to it. The upper box itself is then placed over the exposed half of the pattern, and adjusted accurately in its place by means of pins projecting from the outside of the lower box, as shown in the sketch (Fig. 2). When both halves are in their places, the upper box is then filled with sand through the top, which is open; and this being well packed down, it takes the exact impression of the upper half of the pattern, after which it is removed. The pattern is then taken out of the lower box, leaving its impression; and it can now be readily seen that when the upper half of the box is again placed in its former position, an exact mould has been formed, into which the melted iron can be poured and allowed to remain till it becomes solid and cool. The art of the moulder consists chiefly in making good any defects which invariably occur in removing the "pattern," as little bits of sand adhere to it or break away from the corners of the sandy mould. A great variety of neat little iron tools are used for this purpose, and require great practice and a steady hand to use them with precision. The finishing work before the mould is "poured," is to dust the interior over with charcoal or lamp-black, and then rub the surfaces with a smoothing-tool, giving a sort of lustre that is reproduced to some extent in the casting. A "pouring hole," and "vent holes," to allow the heated gases to escape from the molten metal, complete the operation. The case of a solid cylinder is one of the very simplest forms of patterns of moulds and castings that exist, because the first is produced with great ease in a turning-

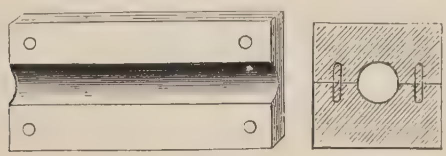


Fig. 3.

lathe, and the others in the easy manner already described. We will now suppose that a hole is wanted to be put through the cylinder from end to end. For this another pattern is required, called a "core box." It consists of two pieces of wood laid together very much in the same way as the boxes of the foundry, and kept in their place by means of pins projecting from their surfaces. Each of the halves is cut out, so as to form a half of the pattern of the core, as shown in the sketch (Fig. 3). The duty of making these cores generally falls to the lot of the younger apprentice moulders, and is an operation requiring no great skill or practice. A mixture of clay and rough sand is simply put into the box, very often supported through the centre with a piece of iron rod, or made up with straw ropes, to give it sufficient strength to support its own weight. When it has been moulded in the "core box," it is then carried—and this is an operation that tests the patience of the neophite, as it is very apt to break—to the Stove. This is a building about 7 or 8 feet in height, about the same width, and of a sufficient length to receive the long "cores" that are frequently required for making steam, water, and gas pipes. As a fire is kept burning inside,

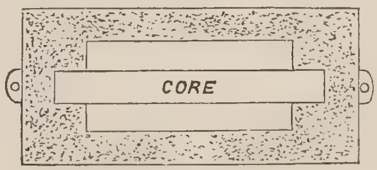


Fig. 4.

and the heat retained by the closing of iron doors, going into this black and fiery dungeon to look after the "cores," and see how they are baking, is not the least of the many grimy details in the occupation of an iron moulder. When the core is dried, it is placed in the mould of the cylinder we have already described; and for this purpose the pattern has projections at its ends called "prints," the exact diameter of the "core," which, as they make recesses at each end, provide a support for the core, as shown in the sketch (Fig. 4). It will now be readily seen that, when the molten iron is poured into the mould, it runs all round the "core," leaving it in the centre, so that, when the casting is cold, the sand of which the "core" is composed can be readily removed, leaving the required hole through the centre of the cylinder.

We have taken the very simplest form of pattern to illustrate the process; but the reader can easily understand that such elaborate patterns as those that form the complicated details of steam engines require a much more elaborate mould, and great skill on the part of the workmen whose business it is to cast them. The larger castings—such as

the propellers and condensers and cylinders of marine engines—are manufactured in a totally different way. In the case of these heavy castings, the weight of the molten metal rushing round the corners and through the interstices would be certain to destroy the mould, and so the same material is employed of which the "cores" are made; only, instead of interior make-shifts of straw-ropes and small bars of iron, they are built of brick, with a sufficient thickness of the mixture of wet sand and clay plastered over them. It is a grand sight to see one of these large castings being "poured," consisting, as they often do before being closed in, of what appears more like the foundation of a house dug deep down—perhaps 10 or 12 feet—than a structure that has merely to fulfil the temporary purposes of a mould. In forming them, no patterns such as those we have described are needed, nearly everything being done by "sweeps," which are made of pieces of wood shaped in such a way that, when their edge is scraped over the surface of the wet mixture of sand and clay, they leave the required form on its surface. When these large moulds are finished, the greatest care requires to be taken to have them dried properly, as any moisture would certainly lead to an explosion. This process of drying is a very tedious one, and is carried out simply by kindling fires of wood and coal in different parts of the mould, and keeping them in for many days, if necessary, until the drying process is complete. As provision has to be made for every particle of sand being removed from the casting, it is no easy matter to arrange for this being done; and it sometimes requires great labour and trouble to remove "core irons," more especially from those passages for steam in the cylinders of steam engines that are necessarily intricate.

We have illustrated the simplest form of pattern and mould, in order to afford the reader a general idea of how castings are produced; but it would be beyond the scope of the present paper to go into the details of the special industries that have risen within recent years, such as "sanitary castings" and "ornamental castings." These have grown up under the fostering influences of commercial competition, and the success that attends these undertakings depends altogether upon the application of ingenious methods of production, which save time, labour, and material. The Colebrook Dale Iron Works, with which the fathers of iron founding, the Darbys, were so long and so honourably connected, still holds the foremost place in the United Kingdom for the production of ornamental castings. These have been frequently the admiration of visitors to the various international exhibitions; but, although they are marvellous specimens of the moulder's art, they are far exceeded by the productions of the Hartz Mountains, in Germany, where castings are produced that have almost the finish and appearance of oxidised electro-plates. The principal demand for ornamental castings occurs in the manufacture of what are called "American stoves," where a good pattern gets a name to itself, and is reproduced in thousands. The West of Scotland has acquired a great pre-eminence in this particular industry, which has been established from the early days of iron founding at the well-known Carron Iron Works, which gave their name to the carronades that were once so famous in our naval warfare. Among recent processes in the art of the iron founder, there is one that has acquired considerable importance. It consists in softening castings by annealing them, and at the same time putting them in a "dry bath" of some substance that has a great affinity for carbon, and which removes a large portion of it to some depth from the surface. The effect of this is to give the castings, especially when they are small, the character of wrought iron, which the reader can better understand by referring to a previous paper, in which it was explained that the principal difference between cast and wrought iron consisted in the former being much more highly carbonised. This process has greatly developed in the "sewing-machine trade," where the elaborate forms required for the different parts of that wonderful piece of mechanism, that were formerly made by the blacksmith at the expense of much labour, are now formed first in moulds at a very small cost, and afterwards turned into a species of wrought iron by this process of "decarbonising." The substances employed in the "dry bath" for producing malleable cast iron are generally the secret of each individual establishment; but a very effective one consists simply of hæmatite iron ore.

In our next paper we propose to take up the subject of Wrought Iron.

HEALTH AND DISEASE IN INDUSTRIAL OCCUPATIONS.—III.

THE DIRECT CAUSES OF INDUSTRIAL DISEASE.

By W. Gordon Hogg, M.D., late Senior President of the Royal Medical Society, Edinburgh.

ROMANCE has cast its halo around the ghosts which haunt the corridors of some ancestral mansions, by way of picturesquely marking the untimely end of former occupants. It may be also that not a few pale spectres flit through the passages of prosaic factories when the spindles are still, silently protesting against the negligence which robbed us of their not valueless lives when they were beings incorporate in the flesh. The premature decay of factory workers may lack individual interest, but the combined records of the dead compel our attention by their startling reproaches. Let us give the fullest value to the taunts of intemperance, reckless expenditure, or thriftless ways; yet there remains the fact that in some trades the worker loses health, and often life, irrespective of these influences, and solely by the direct influence of his occupation.

The object of these papers is to ascertain to what extent a man with a sound constitution, with temperate habits and with favourable environments, is necessarily affected in health by his employment. In order to discover the absolute unhealthiness of trades, the errors of life in the worker, as distinct altogether from the influence of toil, must be eliminated. What is now aimed at, therefore, is to show the pure and simple effects of physical occupation on the vital capacity. The habits of the operative *after* work stand in a secondary position. At the same time, it must with all charity be borne in mind that these habits may be engendered, to a certain extent, in consequence of the peculiarly depressing influences of the industry in which he engages. There can be no doubt that intemperance and neglect of sanitary laws will materially reduce the normal "threescore years and ten" allotted to mankind by the Psalmist, whatever be the occupation. But, putting ourselves in the precise condition of the industrial classes, how few of us could throw a stone at any one of them! The public-house or music-hall was, till of late years, the only place of amusement and relaxation open to our operatives. Many philanthropic exertions in behalf of working men were based on the idea that they were already educated up to the pitch of finding amusement in matters congenial to their more refined well-wishers; but these schemes have been only partially, if at all, successful. Again, to talk of home and its family pleasures is a mockery to a man whose wife knows not how to make home attractive. If mill girls or domestic servants possessed the rare accomplishment of house management, there would be little or no excuse for the dissipation of artisans.. But this art is the heritage to some extent of refinement, and to a great extent mainly of education and sound sense.

Consider also the monotonous labour of the artisan; his hands fall to one automatic routine. "He feels, each anxious hour, that the dull treadmill by which is secured the means of sustenance for a hungry household may, without warning, be closed by any number of forces over which he has no control." He has to work with the same crowd of people, in the same building, at the same ever-repeating labour, while his brain is left unemployed, to brood over real or imaginary evils: these conditions affect life to the core, and so we must indeed make many allowances for the factory worker.

Attention must, however, now be directed to the immediate causes of disease in various industries, regarded quite apart from the complicating influences of personal habit. With the present hours of employment, no actual disease can be directly traced to mere strain of physical labour. Trades unions, aided by the not unnatural disinclination of the operative for over-work, have put an end to excessive taxation of the physical organs. Besides, hard work is not in itself unhealthy; indeed, minus worry, it is an excellent tonic. Given, then, a sound constitution to start with, what are the occupations to which an Industrial Life Insurance Company would attach high premiums? Though not strictly an industrial calling, we may, for comparison, state that the highest rate would have to be paid by publicans. This section of the community need not want for plenty of food, air, or society (of a kind); yet, hard facts show that the life-value of the publican is, when compared with that of all other tradesmen, the lowest in the scale. In all England, exclusive of London, the mortality of all males from 1861–1871 was at the rate of 1·182 per cent. annually. But of publicans it was nearly three times as great, or, to put it exactly, 3·163 per cent. annually. To state comparative details more minutely, it may be remarked that, at 35 years of age, the mortality was, for all classes, 1·305; for labourers, 1·080;

for blacksmiths, 1·124; for railway servants, 1·497; for publicans, 2·044. There is an old cynical proverb which runs "the nearer the church, the farther from grace." These figures might give us, as a parody of it, "the nearer the public-house, the farther from health and longevity." Besides the trade of liquor selling, the following occupations would also have to be highly rated:—Flax and cotton workers, needle makers, workers in earthenware, knife grinders, plumbers and painters, and miners.

I propose to take each trade in detail, endeavouring to state what are the habits and diet of the worker, to show how far he is injuriously affected while at work, and to suggest remedies where it is possible to do so.

In a series of popular papers such as these, it would be, for many reasons, unadvisable to enter minutely into the pathology, or morbid anatomy, of special diseases. But for the sake of order and clearness, a rough classification may be adopted, based on the causes which produce disease in the industrial classes, that can be directly traced to unhealthy occupations. We may start by saying that the most prevalent causes of special trade disease are:—(1) The inhalation by the lungs of fine particles of solid matter, or of gases and vapours. (2) Exposure to damp, and to impure air; under which head may be included the exposure to extreme variations of temperature. (3) Exposure of the body to chemical agents. (4) Injuries from unnatural positions, from burns and scalds, and from bearing weights and loads. The Special Report of Dr. Ballard for 1877 to the Local Government Board might suggest the addition of a fifth set of causes—namely, noxious effluvia. But these, to some extent, are included under the heading of "Gases and Vapours," though at the same time it must never be forgotten that bad smells do not necessarily cause disease. They are like the rattle of the poisonous snake, which indicates the presence of a hidden foe. Nausea and sickness may arise at the moment, but the more subtle poisons, or germs, which attack the system, are slow in manifesting their presence and effects. Dr. Ballard describes a model fellmongering establishment with the enthusiasm of an ardent sanitarian, and his conclusions are, that with the use of improved appliances, and scrupulous cleanliness, no special disease will be generated.

Under the first head, the various forms of dusts which are thrown off from many substances in the process of manufacture are dealt with. These dusts produce special symptoms, in accordance with their physical characteristics. There are cutting dusts, formed of hard particles with cutting edges, which arise during the grinding of iron and steel, of glass and earthenware. There are irritating or prickly dusts, derived from textile fabrics, wool, cotton, flax, or clay. There are chemically poisonous dusts, given off during the colouring of fabrics by arsenical or other salts.

In fact, nature has foreseen the risks which man ordinarily runs from dust inhalation, and has accordingly provided him with a protection against moderate exposure to the above-named influences. Beginning at the entrance to the nose, we find the moustache placed in males so as to act as a sort of air-filter and respirator. Any one who watches stone-cutters at work, can see how powdered dust is checked in its progress towards the nose and lungs, and how it is deposited thickly on their beards and moustaches. Next are found, within the cavity of the nose, numerous hairs growing crosswise, like a thick-set fence, to check intrusion. Thirdly, a microscope will disclose a beautiful provision for expelling foreign substances. Throughout the whole course of the lining membrane of the throat, of the wind-pipe, and of the bronchial tubes are studded minute filaments, called "cilia," from their supposed resemblance to eyelashes. They are extremely small, and can only be seen by aid of a powerful microscope; but they are in constant movement, invariably waving in one direction—that is to say, from within outwards. They are, as it were, constantly beating or lashing themselves against the current of air taken into the lungs. Their motion is singularly beautiful, and where they are most numerous it has been compared to that of a waving field of corn. When any fine dust or mucus enters the lung with the inspired air, these waving filaments sweep it outwards, till it gradually reaches the mouth or throat, when it may be swallowed or spat out. The black mucus seen in the expectoration from the lungs of a Londoner is caused by the fine particles of soot waved up by the "cilia," and mingled with phlegm which is coughed up. Fourthly, nature protects us by means of the mechanism which produces coughing. If any irritating particles enter the wind-pipe, a message is sent up to one of the nerve centres. The reply takes the form of a violent muscular contraction of the lungs and walls of the chest, by which the intruder is dislodged. Fifthly, the windpipe and bronchial tubes, when irritated, secrete a viscid fluid, known as "mucus" or phlegm

which encircles the dust, and is then either coughed up or borne outwards by the "cilia." If a particle of salt is placed on a snail, it causes great discomfort; but very soon a frothy secretion exudes from the creature, which entangles and lifts away the irritant. The same process occurs within the lung. If, however, the "cilia," the cough, the mucus, and the hair guards are overpowered by the quantity of dust, a portion of it passes these protecting obstacles and enters the cells of the lungs, and then mischief supervenes. Particles of glass, steel, or fine stone sometimes actually cut the "cilia" through, and even pierce the lining of the lung as well. Hence the fatal effects of their occupation upon knife grinders, stone cutters, needle pointers, and sand-paper makers. Inflammation is set up by the inhaled particles, the lung breaks down, and grinder's "rot," or industrial phthisis, is the consequence. Again, if the dusts be not mechanically irritating, they may be chemically so. The dust of arsenic or mercury, when used among furriers or paper makers, enters the lungs, and a portion is at the same time swallowed. In such cases, we find distinct symptoms of specific poisoning, without injury to the lung. The chemical agent attacks the system, being absorbed through the lungs or stomach, and of course shows its special effects in due time. With textile fabrics, the particles of cotton, from their elastic and sharp structure, cause much distress; while those of wool or silk, being soft and oily, are less hurtful. The dust given off in the various stages of flax preparing also produces the most serious and obstinate form of industrial disease, to which particular attention will be directed in another paper. Among miners, the coal dust frequently plugs up the lungs to such a degree that large portions of them are found, after death, to be solid.

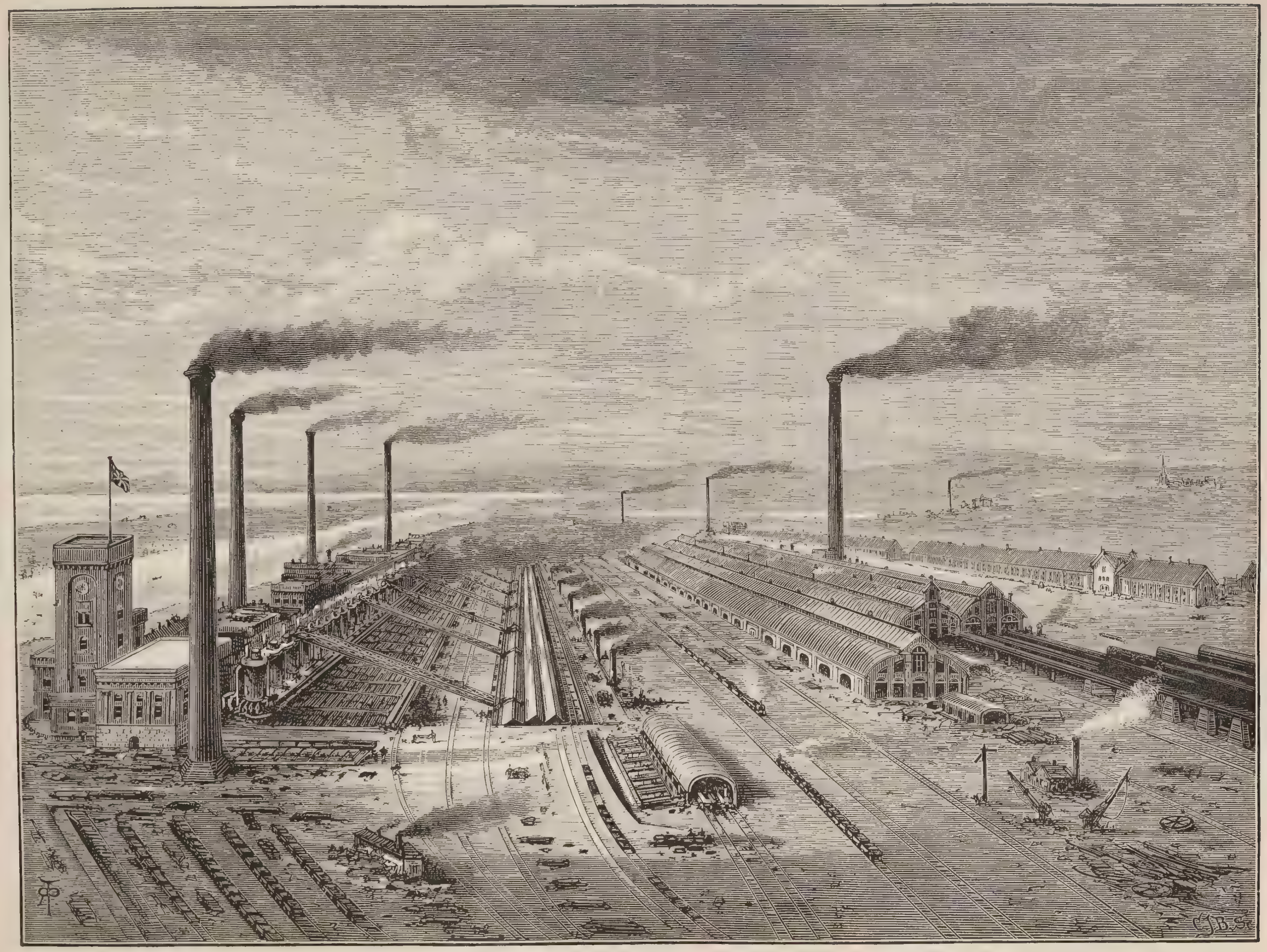
With regard to exposure to damp, wet, and extremes of temperature, it will be found that much suffering arises from the heated condition of factories. Badly ventilated, full of steam and draughts, what wonder is it that bronchitis and consumption are engendered or fostered in such places? Among the potters also are found some curious typical forms of industrial disease, directly occasioned by their work. It must, however, be remembered that a clay soil is damp and cold, and has of itself a tendency to produce special disease. When, then, the outward influences are unfavourable, as well as the occupation, the symptoms of disease are more intense. We have now given indications of the groups of industrial sickness that must be considered in detail. Nearly all the organs of the body are apt to be attacked. Industrial work of various kinds may produce in the lungs of the operative—consumption, bronchitis, asthma; in their hearts—palpitation, intermittent action, bloodlessness; in their stomachs—dyspepsia, vomiting, diarrhœa, constipation, colic; in their skin—ulceration and eruptions; in their brains and nervous system—headache, dizziness, paralysis, neuralgia. There is no doubt whatever that by far the greater number of these maladies might be eliminated from the catalogue, if proper precautions were insisted on by the employers, and carried out by the workers. The issues at stake are, it will be seen, of serious importance. The annual death rate in England and Wales being taken at 25 in the 1,000, that of the industrial community stands at 27 in the 1,000. The former figures represent an annual mortality of 125,000 in the 5,000,000, the latter of 135,000 in the 5,000,000; consequently, industrial disease robs us of 10,000 lives annually. When there is added to this death roll the great physical suffering which accompanies trade diseases, the loss of wages during periods of prolonged sickness, surely our earnest attention is urgently demanded to a sanitary reformation. There are about 900 factory surgeons throughout the kingdom, and right well are their duties discharged, in spite of miserable pay. But their powers of beneficial interference are too narrowly bounded by stringent "regulations." They, of course, have the privilege of sending in "reports" to the Local Government Board; but, as a satire on State sanitation, it is from these *past* and present reports that the facts regarding *existing* preventible trade disease are gathered. The central authority has the strength of a giant; but it is, as all local governing bodies know, chained in the fetters of a stolid, immovable officialism. Were the factory surgeons intrusted with more extensive powers, a happier era might dawn on us; but, as it now stands, they are well-nigh sick of pointing out evils that are ignored, and of suggesting remedies that nobody will use.

MODEL ESTABLISHMENTS.—III.

BARROW IRON AND STEEL WORKS.

By Alfred Ewen Fletcher.

ALONG the western sea-board of the beautiful Furness peninsula stretches the scene of a remarkable triumph of industrial enterprise. The thriving town of Barrow, with its magnificent docks, and stately chimneys, its wide, open streets, and huge blocks of red sandstone buildings, now occupies territory but a few years ago held in fealty to solitude. Until the elder Brogden accomplished the great work of carrying a railway across the sands of Morecambe Bay, notwithstanding the obstacles encountered at the turbulent estuaries of the Kent and Leven, Furness was shut out from convenient communication with the rest of the world. Bounded on the north by the grand Cumberland mountains, and east, west, and south by the sea, its isolation and picturesqueness early attracted the attention of the "pious monks of St. Bernard," who in the beginning of the twelfth century selected one of the loveliest of its secluded valleys for the foundation of a religious house. The noble ruins of this establishment still stand as mural evidences of the tender grace of a day that is dead, and when lit up at night by the glow from the great blast furnaces at Barrow, bear silent witness to the contrast between the present and the past. It was probably also owing to the advantages which such an out-of-the-way place as Furness then was offered for the initiation of an armed rebellion, that Lambert Simnel selected it for effecting a landing when, with a band of Irish followers, he entered upon his madcap expedition to wrest the crown of England from King Henry VII. Previous to the construction of the over-sands railway, which followed Mr. H. W. Schneider's discovery of the hidden treasures which nature has been accumulating for ages in this favoured promontory, Barrow was but a topographical expression. It consisted merely of a collection of fishermen's huts, and gave little promise of its ever becoming an adopted home of the arts practised by Vulcan and his swarthy Titans. But the town has since sprung up with a rapidity unprecedented on this side the Atlantic. Until very recently, it escaped the vigilance of the map-makers, and still continues to play havoc with the trustworthiness of the census returns. In 1845, the population of Barrow was less than 300. The Government return for 1871 showed that the number had risen to over 18,000. But this return held good for only a very short time, for according to a census taken by order of the Town Council in 1875, the number had risen to 42,000, showing an increase of considerably more than cent. per cent. in four years. The ratable value of the borough, which is now a municipality with eight electoral wards, has correspondingly increased. This extraordinary prosperity has been mainly owing to the establishment here of the great iron and steel works, of which we give an illustration on the opposite page. These works are of their kind the largest in the world, and their history, like that of the town which has sprung up around them, contributes one of the most interesting chapters to the annals of industrial enterprise. Commenced with only three blast furnaces by Messrs. Schneider and Hannay, in 1859, they have gradually gone on increasing to their present colossal proportions. The making of ordinary pig iron was all that was at first attempted; but this was carried on with such remarkable success that, a few years later—namely, in 1865—it was resolved to establish works for the conversion of the pigs into steel for rails, tyres, axles, plates, &c. For this purpose a company, promoted by Sir James Ramsden, was formed under the chairmanship of the Duke of Devonshire, to whose fostering care Barrow is mainly indebted for its rapid development. The Duke of Buccleuch, who owns much of the royalties of the mines in the district, has also taken an active share in the initiation of the Barrow industries. The new company purchased Messrs. Schneider and Hannay's works, and also the interest in their rich hæmatite mines. The Furness ore is better adapted than any other for conversion into steel on the Bessemer process, and hence it was considered that the establishment of works for carrying out this valuable process on an extensive scale could not fail to be a success. The most sanguine anticipations of the shareholders have since been realised. The average dividend since the commencement has been about 20 per cent. per annum. In addition to the Duke of Devonshire, the directorate included Lord Frederick Cavendish, Sir James Ramsden, Messrs. Schneider, Hannay, John Fell, and J. T. Smith, the responsible manager.



The Iron and Steel Works, Barrow.

The works are situated on an open plain, eastward of the channel that divides the Isle of Walney from the mainland. On a clear day, when viewed as a whole, with wreaths of white smoke from their lofty chimneys sailing away to the distant hills where Black Coomb "looks from his giant throne" across the Irish Sea, the works present a scene of mingled activity and picturesqueness, irresistibly suggestive of man's rivalry with Nature for mastery over forces of which the latter can no longer claim a monopoly. Numerous lines of railway divide the Iron Works from the Steel Works. The former, which are represented on the left-hand side of the illustration, consist of sixteen blast furnaces, which are capable of turning out 300,000 tons of pig iron per annum. They are 60 feet in height, and have an average diameter of 20 feet at the boshes. In front of the furnaces are the neatly-furrowed sand beds, into which the molten iron is run into pigs. The process of tapping the furnaces presents a beautiful appearance, especially at night-time. Raised above the pig beds are the inclined planes, up which, by means of winding engines, the railway trucks containing the ore and fuel are drawn to the top of the furnaces to discharge their contents. The fuel used in reducing the ore is coke, with a proportion of limestone used as a flux. The former is brought from a distance, as no coal has yet been discovered in Furness; but the latter is found plentifully in the neighbourhood. About 1,000 tons of coke are consumed at these works every day, and the annual consumption of ore (hæmatite) is over half a million tons. The engines for supplying the blast are placed in the rectangular buildings in the rear of the furnaces. To watch the movements of these enormous machines is to be impressed with the conviction that they are fearfully and wonderfully made. They seem to be endowed with the genius of the poetry of motion. They have an aggregate force of 4,400 horse-power. It is hardly possible to give an adequate idea of their marvellous mechanism, of their tremendous power, or of the splendid order in which they are kept. Behind the furnaces, and communicating with them, runs at an elevation from the ground a cylindrical tube 700 feet in length, containing the air required for the blast, and which before entering the furnaces is heated in enormous stoves to 800° or 900° Fahrenheit. Farther in the rear towards the channel are situated the terraces of boilers which supply steam for the engines. No coal or coke is used in heating the boilers at the Iron Works. The fuel brought into service for this purpose consists merely of the gases generated by the combustion and fusion of the coke, limestone, and ore, in the blast furnaces. These gases are conveyed to the boilers by means of pipes truncated from the blast furnace towards the top. Formerly blast furnaces were constructed with open tops, and the gases were given out with a brilliancy that lit up the surrounding country for many miles. The loss of this weird picturesqueness has been more than compensated for by the great saving in coal which the adoption of the closed or bell-top principle has effected. Of the 300,000 tons of pig iron annually turned out from these sixteen blast furnaces, about one-half is sent into the market to be manufactured into finished iron elsewhere. The other half, or about 150,000 tons, is made into steel by the company.

The history of the Steel Works (see the range of buildings to the right of the lines of railway in the illustration) is the history of the Bessemer process, which from the successful and gigantic operations carried on here, has now been fairly established as one of the most remarkable discoveries of the age. The Bessemer process, which will be found more fully described in another portion of this work, consists of the conversion of iron into steel by the admixture of a small proportion of spiegeleisen after the molten pig iron has been freed from every contained impurity by a powerful blast driven through the mass when in the converters. These converters are large, somewhat oval-shaped retorts, truncated at the butt end, and have a capacity for 6 tons of molten metal. When Mr. Bessemer first explained his process to the assembled scientists of the British Association, he was laughed at by the majority of that learned body. To commence with being ridiculed, however, seems to be a *sine quâ non* of success in this world, and most "enterprises of great pith and moment" are initiated in laughter. But Mr. Bessemer has long since lived down ridicule, and his process, thanks to the splendid manipulation it has undergone at these great works at Barrow, under the superintendence of Mr. J. T. Smith, has affected a complete industrial revolution. The manufacture of iron rails is now all but discarded, while the immense superiority of those made from Bessemer steel is universally acknowledged, as they last six or seven times as long as iron rails. Nearly all the great railways that have been constructed both in Europe and America of late years, have been supplied with rails from Barrow.

The vast workshop in which these Bessemer rails are manufactured consists of one great shed, 750

feet in length and 300 in width. The whole is covered with a roof divided into three bays, and supported on wrought-iron girders, weighing in the aggregate 200 tons. The scene within this great hive of industry, when the various operations are in full play, is of the most animated and interesting character. Leaving the Iron Works by a light iron foot-bridge that crosses the railway, and entering the Steel Works at the north end of the shed, attention is at once attracted to the men engaged at their perilous work in the large circular pits, round which are ranged the moulds into which the white-hot liquid steel is run when the converters are ready to be tapped. There are eight of these pits, each supplied by two converters. These immense retorts are raised a little above the pits, and are movable as on a pivot. The heat given out during the process of filling the moulds is intense enough to be anything but comfortable even to the spectator, whose astonishment is awakened at the fire-resisting virtues of the men in the pit, who are engaged in raking about the molten contents of the converters overhead. Until recently the converters were supplied by thirty-four cupola furnaces, eighteen of which were used for melting the pigs, and sixteen for the fusion of the spiegeleisen. But the process of melting the pigs has now been done away with, the molten iron being conveyed in vessels constructed for the purpose, direct from the blast furnaces at the Iron Works. The converters are supplied with tuyeres or small apertures through which the blast is driven at a pressure of 25 lb. to the square inch. At a certain stage in the blowing operations, a beautiful pyrotechnic display is produced. The engines required for driving this powerful blast have an aggregate force of 5,000 horse-power. When the process is finished, and the spiegeleisen has been added, the metal is run into the moulds already alluded to. When sufficiently cooled, the ingots are taken out of the moulds and wheeled on small trucks to the gas-regenerating oven, situated lower down in the shed, to be re-heated. Opposite these ovens, and occupying the middle of the shed, are a series of immense steam hammers, under which the re-heated ingots used to be placed to be beaten as with the hammer of Thor. But the method of hammering the ingots is gradually being discontinued, the squeezing process being now in more favour. When, therefore, the ingots are taken from the ovens, men and boys may be seen wheeling the white-hot blocks across the building to the rail mills, where the solid mass is squeezed out and gradually elongated until it at length emerges in serpent-like form from the final revolving groove of the mill. It then stretches itself out upon the floor, and being cut into the requisite length, is slided off while still red-hot to the nearest pile of finished rails. The monster fly-wheels to the machinery used in the operations are placed in the middle of the building, and the rapidity of their revolutions keeps up a perpetual whirring accompaniment to the thud of the hammers, the clanging of masses of metal, and the roar of the furnaces.

At a short distance from the southern entrance to the shed are placed the gas producers for the re-heating ovens, and in the rear of these is the reservoir belonging to the works. A range of buildings on the east or main entrance side of the entire works, consist of the general offices of the company, engineers' shops, the testing house, &c. In this last-mentioned department, demonstrative evidence of the virtue of Bessemer steel may be seen in the form of rails twisted when cold into fancy knots, screws, and all manner of fantastic shapes.

The general organisation throughout the whole of this vast establishment everywhere affords evidence of the active brain and intelligent business capacity of its controller. The amicable relations existing here between masters and men have only once been temporarily disturbed, and on that occasion the dispute was confined to one section of the workmen. The company have ever been solicitous for the welfare of their employés. The provision of adequate house accommodation, one of the great difficulties they have had to contend with, owing to the rapidity of the growth of the population in Barrow, has been overcome; the company having either built themselves, or secured on long lease, whole streets of comfortable workmen's houses. The number of hands usually employed in the works is about 3,000, but including the men and boys employed at their iron mines in Furness and the collieries owned by them in Yorkshire and South Wales, the company in their fortnightly wage sheet will have to provide for 10,000 claims when the collieries are fully opened out. This vast concern from comparatively small beginnings has grown up to its present unparalleled magnitude under the active superintendence of Mr. J. T. Smith, who, by the eminent services he has rendered to the iron and steel manufacture, as a practical engineer and administrator of great works, has won for himself a very wide and well-deserved reputation.

WOOL AND WORSTED.—V.

WORSTEDS AND WOOLLENS: WHAT ARE THEY?—SECOND PAPER.

By Walter S. B. McLaren, M.A., Worsted Spinner.

In the first paper upon this subject, it was shown that the common ideas on the distinction between worsted and woollen yarn were all more or less erroneous, and it was pointed out that the real difference between them lay in arrangement of the fibres rather than in the use of particular machinery; for all the principal machinery used in woollen spinning can also be used for worsted.

To make perfectly clear the difference between the two sorts of yarns, it may be worth while to state in a few words how each is made, premising, however, that as the various machines and processes will elsewhere be fully described, it will not be necessary here to enter into any details respecting them: the object at present being merely to show that in all worsted yarns the fibres are straightened out and laid parallel to each other, while in woollen yarns the reverse is the case. Let us first take the four classes of worsted yarns previously mentioned. The first is made of what is called long-combed wool. To straighten the fibres, and thus prepare them for the comb, the wool is put through machines called "gill boxes." The essential principle of a gill box is that a pair of rollers at the back, which revolve slowly, receive the wool, and pass it forward to rows of steel pins, called "fallers," which travel forwards by means of a pair of revolving screws for a foot or eighteen inches, and then drop or fall down, and are carried back again by means of a lower pair of screws, till they reach the rollers at the back, when they are lifted up to their former level, and make the journey again. At the point, however, when the fallers drop—that is to say, at the point where they reach the extremity of their forward journey—another pair of rollers are fixed, which revolve rapidly. These draw the wool off the fallers, so that they always make their return journey empty. Now, as the fallers travel faster than the rollers at the back revolve, and as the rollers at the front revolve faster than the fallers travel, it is plain that the mass of wool is drawn out thinner than it was put in; and that, as the rollers draw the fibres through the steel pins of the fallers, the fibres are constantly being straightened out, and are at last made into a comparatively smooth and level ribbon, called a "sliver." A number of these slivers put together are combed, with the result that all the little lumps and very short fibres of wool are taken out as "*noil*" or waste; and the long, smooth fibres are laid level side by side, and continue in the same relative position through the various processes till they are spun.

For the second class of worsted—namely, that made chiefly of Botany and other short wool—the method of preparing for the comb by means of gill boxes is not suitable; because, the wool being short and fine, the rollers could not open it properly by drawing it through the steel pins of the fallers. Such wool, therefore, is carded, to separate all the fibres and open the little knots. It is afterwards combed, and such knots as are left by the cards are removed, and the longer wool is made to lie smooth and level, as already described.

Take, next, carpet yarn, which is not combed at all, because it is necessary to preserve as much of the short wool as possible. The wool is first carded. But when it comes out of the card in a rather thick "sliver," the fibres lie in all directions, and need to be straightened. For this purpose, it is put through four or five gill boxes, similar to those already described. In this way, the fibres are made almost level; but it is not possible to get the same perfect regularity as those who spin combed wool can easily obtain. This, however, from the purpose to which the yarn is put, is not of much importance.

The fourth class of worsted yarn is that called "knickerbocker." As there must be no knots of wool in it, the wool is combed, after being either prepared in gill boxes or carded, according to its length and quality. It is then necessary to mix the silk noil with it; and to do this thoroughly, the combed wool is generally carded along with the silk noil. After the carding, gill boxes cannot be used to straighten the fibres, because the knots of silk would be pulled into large lumps, or even taken out again. The wool, therefore, is straightened by being drawn out between pairs of rollers, and by care can be made almost as level as if gill boxes were used. Thus it will be seen that, whatever the sort of wool, or whatever the machinery through which the wool passes, the main point to be attended to in worsted spinning is to arrange all the fibres in parallel lines, and to let them lie smoothly. This continues down to the spinning; and though, of course, a certain amount of twist is

put in to make the fibres hold together, it does not disarrange them or remove them from their parallel position.

Let us compare this with the way in which a woollen thread is prepared and spun. The wool, after having been opened out by a machine called a teaser, willey, or devil, is scribbled or carded. If the names are used accurately, it is said to be first scribbled and then carded, but generally the words are used indiscriminately. Finally, it is passed through a particular kind of carding machine, called a "condenser," the peculiarity of which is that, instead of delivering the wool in one thick "sliver," or ribbon, it delivers it in thirty or forty thin ribbons, about an eighth of an inch in diameter, which are wound on to rollers. These thin ribbons, or "slubbings," are taken to the mule spinning frame, and the yarn is spun from them. Now, in these operations there is no attempt to straighten the fibres. The wool is, perhaps, put through two scribbling machines and a condenser. The first scribbler automatically feeds the second, and the second feeds the condenser; but there is an important difference between their method of feeding and that which is employed for gill boxes. In the latter case, the ends of several slivers are put between the rollers of the box, and the whole is gradually pulled through *lengthways.* But in scribbling, the reverse is the case. If the wool comes out in a sliver, there is attached a machine, which lays the sliver in regular lengths *sideways* against the "taking in" or receiving rollers of the next scribbler or card. If the wool does not come out in a sliver, it comes in the form of a broad sheet, which is lapped round a roller; and when a certain thickness has been obtained, it is opened and taken in by the receiving rollers of the next card. By these means, any straightening of the fibres is rendered impossible; and therefore, when the yarn has been spun it is found that the fibres are lying in all directions. If any one takes a thread of worsted and one of woollen, and pulls out the separate fibres, he will find that those drawn from the former will only be slightly waved, while those from the latter will curl up. This is, however, partly affected by the amount of twist in the yarn. It has been said that woollen yarn is spun with very little twist, so as to assist the felting; while worsted yarn is twisted very hard. This is not correct. No general assertion can be made on the subject, as the twist depends on the quality of the wool and the purpose for which it is to be used; but it is quite clear that yarn made of wool of medium length can be spun with less twist for a given strength than if it were made of short wool; and this is the more true now that materials like shoddy and mungo are used in nearly all woollen yarns.

Another remark in reference to carding and combing should be made. It is often stated that one reason why combed wool is not so suitable for milling as carded wool is because the passage of the fibres through the steel pins of the gill boxes and comb breaks off the serratures in the fibres or blunts their points. Consequently, they have not the same power of interlocking as before. Wool that is carded, it is said, does not suffer in the same way, the effect of the operation being to open the serratures and make the fibres rougher. It is very unlikely that this is the case. When it is considered that there are from 1,200 to 3,000 serratures per inch in the fibre, and that the wool is oiled before it is either combed or carded, it will be obvious that the action of the steel pins of the combs or the wires of the cards cannot have much effect upon the small points which are presented to them. But if any are broken off, it is much more likely that the breakage happens in the cards than in the combs, for the treatment the wool receives is much rougher in the former than in the latter. As the fibres are torn and pulled by thousands of short wire pins, placed in rapidly-revolving cylinders, there is every chance that if damage can be done to the points of the serratures it will be in the operation of carding rather than in the comparatively slow and gentle operation of combing. But the oil which is mixed with the wool, no doubt, protects the serratures from breakage, and as it is removed by scouring before the cloth can be milled, the serratures then remain free and open to interlock with each other.

From what has been said, it will be clear that any definition of worsted and woollen yarns cannot depend on the machinery by which they are made, nor on the use to which they may be put after they are spun. Neither can it refer to the length or quality of the wool. The definition must depend entirely upon the characteristics of the yarn as seen in the arrangement of the fibres. A worsted yarn, therefore, may be defined as a thread spun from wool in which the fibres are arranged so as to lie smoothly in the direction of the length of the thread and parallel to each other. The fact that this smoothness is not always obtained does not invalidate the definition, but simply shows either the refractory nature of the wool, or the

imperfection of the machinery or workmanship. The definition remains correct, and the more nearly worsted yarn approaches perfection the more nearly does it approximate to the above definition. A woollen yarn, on the other hand, is a thread spun from wool in which the fibres are arranged so as to lie in every direction, and cross and overlap each other that they may present their serrated surfaces in the greatest variety of directions. This crossing and overlapping of the fibres is the characteristic of woollen yarn; and whatever change there may be in the machinery by which wool is spun, the object of the woollen spinner will always be to have yarn in which the serrated surface of the fibres will present themselves in every direction, while the object of the worsted spinner will be to have a smooth and level thread.

It might be supposed, when such is the difference between these two sorts of yarn, that it would always be easy to distinguish them. Generally it is easy; but if a quantity of, say, short fine wool be divided, and half of it spun into worsted and the other half into woollen yarn of the same thickness, and with the same amount of twist, it is surprising to find how little difference there is between them. Nevertheless, a person who is engaged in the trade can, as a rule, tell at a glance whether any yarn is worsted or woollen. But if a stranger were to undertake the task, he would often be puzzled; and this would be especially the case if the yarn were woven into cloth. This is a matter of great importance as regards the customs dues imposed in other countries. The definitions stated above are all that can be given: but they would not be sufficient for a custom-house officer who had not a practical acquaintance with the materials in question; and they would be of no use to him if he had to deal with worsted or woollen cloths, especially if both were milled, as is sometimes the case. The question of whether there should be customs duties at all it is not proposed to discuss; though it may be remarked, in passing, that yarn as a semi-raw material, which must be woven before it can be of use to the consumer, should not be treated as if it were a finished article. But, however that may be, it is of great importance that if there are duties they should be levied upon worsted and woollen fabrics alike, and that they should be *ad valorem* rather than specific. Worsted fabrics especially are so often mixed with cotton or other material, that specific duties give rise to endless disputes and misunderstandings. To attempt to distinguish, for custom-house purposes, between worsteds and woollens is to increase such disputes still further, for the ever-changing fashions and modes of manufacture render the task hopeless. For manufacturing purposes the distinction between the two is clear to those who care to understand it; but if foreign Governments resolve to levy duties they should be content to adopt the *ad valorem* principle, and thereby as little as possible to harass manufacturers.

Having said so much of worsted, a history of the name may be of interest. The derivation of the word "worsted" has been a matter of some dispute. The one generally accepted is that the name of the yarn is derived from the town of Worstead, in Norfolk, either because it was first made there, or because the spinning of this particular class of yarn was there carried to a high degree of excellence. Another explanation is that the name is a corruption of the Dutch word *ostade*, which means a worsted thread. It is supposed that the Flemish weavers who settled in England in the time of the Conqueror, or shortly afterwards, introduced the spinning of this yarn, and called it by their own word *ostade*, which became changed into "worsted." A third derivation is given by Archdeacon Nares, who says that the "woollen thread, yarn, and stuff might naturally be termed "woolstead" as being the staple or substance of the wool;" and was corrupted to worsted by the common change of the letter *l* for *r*. It is argued that worsted yarn must have been known as long as the spinning of wool or the manufacture of cloth, and hence the name could not have been derived from that of the town of Worstead, but rather the name of the town must have been derived from that of the yarn. This explanation meets with but little favour. It certainly is plausible, but appears to be founded on the assumption that the class of yarn in question has borne the name of worsted since it was first made. For this conjecture there does not seem to be any foundation. The spinning of long wool probably preceded that of short wool; but it by no means follows that the yarn so produced was called woolstead or worsted. The probability is—and we do not know of any proof to the contrary—that there was no distinction in name between the two classes of yarn (if, indeed, two classes existed) for many centuries after wool was first spun in England; and it is known that even in the time of Henry VII. worsted and woollen yarns and fabrics were sometimes called "woollen" indiscriminately. With the rude spinning-wheel used in early times all the yarn would be spun in much the same way, the

endeavour being to obtain as long a fibre as possible, and to have all the fibres lying in the same direction. This would constitute it worsted yarn by nature (though rough); but no doubt it would simply be called a thread made of wool, or a woollen thread. At some period, however, a separation between the two classes of yarn must have arisen; and this is most likely to have taken place at a time when a decided improvement in spinning and manufacturing was introduced, and at the place where the improvement originated. Now, in the reigns of William the Conqueror and Henry I., such improvements were introduced, owing to the settlement of Flemish weavers in England, and especially in Norfolk. Norwich, and the other towns in the county—of which Worstead was one—were the chief places where these Flemings settled. It is believed, therefore, that those who carried on their business in the town of Worstead turned their attention to spinning, and produced a yarn which became famous under the name of worsted yarn. The improvement, no doubt, consisted in a better method of straightening the fibres, which, as has already been explained, is the distinguishing feature of worsted thread; and possibly the improvement consisted in some rude method of hand combing. If so, the short wool thus separated from the long, and all the wool which was not thus prepared by the spinners of Worstead, would be spun in the old-fashioned way, and would retain its old name of woollen thread. As the town of Worstead is mentioned in the Doomsday Book as having existed in the time of Edward the Confessor, it is clear that it cannot have derived its name from any manufacture introduced by Flemings in the time of William. This tends to upset the theory that the name is derived from ostade, and makes it more probable that the Dutch name ostade is derived from the English worsted, because the great bulk of Flemish worsted fabrics were made of long wool exported from England, and especially from Norfolk. But though it seems almost certain the town of Worstead had acquired that name before it was given to a special kind of yarn, and that thus the yarn derived its name from the town where it was made, yet the derivation of the name of the *town* is, no doubt, "Wolstede," or the place of wool; and, according to Mr. George Taylor, it is so called in the oldest documents. Long ago the place may have been a wool market or place for "pitching" wool, from being in a convenient situation: and thus its name arose. Curious it is that a town should first have gained its name by being a station for the raw material, and after somewhat altering that name, should in its turn have given it to the manufactured article.

There are no means of telling precisely when the name worsted was first given to yarn spun from wool. The first time it is mentioned is in the eighth year of Edward II. (1315), when a complaint was made to Parliament that the clothiers of Norwich who manufactured worsteds, cogwares, veses, or old hames (all of which names signified the same class of goods), were making them twenty-five yards long instead of thirty, and yet were selling them as if they were full length. From this time the name worsted often occurs, and the yarn seems to have been spun in other parts of the country. The town of Worstead, however, long remained one of the chief, as it is admitted to have been one of the first (if not the first), seats of the worsted trade in England; and its church was built by the Flemish weavers.

WORSTEAD CHURCH.

HEMP, FLAX, AND JUTE.—V.

HOW FLAX IS PULLED, RIPPLED, AND RETTED—EXPERIMENTS IN EXTRACTING THE FIBRE.

By David Bremner, Author of "The Industries of Scotland."

IN order to secure the largest amount of fibre, flax, instead of being reaped, like wheat and other crops, is pulled up by the roots. As the quality of the fibre depends on the degree of ripeness that the plant has attained at the time of pulling, care has to be taken in the selection of the best time for performing that operation; and usually the period of the in-gathering of the crop is an anxious one with the flax farmer. Fine weather is essential at the time of pulling, and waiting for that occasionally leads to the crop becoming over-ripe. The persons employed to pull the flax have to exercise great care in their work. Owing to circumstances connected with the preparation of the ground, it sometimes happens that the stems are irregular in length, and when such is the case, the long and short stalks have to be kept separate, and a great waste of time is the consequence.

Flax Pulling.

Knowing this from experience, the farmer usually does his best to avoid irregular growth by making his ground as fine and level as possible, and covering the seed to an equal depth. When these precautions have been taken, the crop will come up of an even length. The pullers seize a handful of stalks just below the bolls, and, having drawn the roots from the earth, shake them to remove the soil. In order to facilitate subsequent operations, the handfuls are placed one over the other in a diagonal position, so that they may be kept distinct, and thus arranged are bound into sheaves.

The next thing to be done is to strip off the seed-vessels, and this is usually accomplished on the field, simultaneously with the pulling. Even when growth of seed is restricted, in order to improve the fibre, it is a valuable part of the crop, the yield of an acre being worth from £3 to £4. The process by which the seed-vessels are removed is called "rippling," and the apparatus employed, which is of the simplest kind, is known as a "ripple." It consists of a row of stout spikes of iron, fastened to a plank supported on trestles. The most approved ripples are made of square rods of iron, eighteen inches long, half an inch thick at the lower end, and tapered slightly towards the point. The ripple is fixed upon the plank in a transverse position, and the persons using it sit astride the plank at either end. A large sheet is spread beneath, to receive the bolls as they are stripped off. Some sheaves of flax having been supplied to the ripplers, they are ready to begin operations. This they do by untying the sheaf-bands, and then, taking up each a handful of flax, they draw the upper part through the ripple. The bolls, being too large to pass between the spikes, become detached, and tumble into the cloth beneath. As each handful is rippled, it is deposited on the ground, being, as in the case of pulling, kept distinct from its fellows by being placed diagonally. When the sheaf is completed, its band is again put on, and it is set aside ready for the next process. Should the weather be favourable, the bolls are allowed to remain spread out on the winnowing sheets for a day or two to dry, being turned from time to time. In order to give the air freer access to the seed, it is usual in such cases to riddle out the straw and leaves. When the weather is not suitable for drying in the open air, the bolls are taken indoors, and spread out thinly on the barn floor, or other convenient place. By being dried slowly, the seed has time to imbibe all the juices that remain in the husk, and to become perfectly ripe. If dried hurriedly in a kiln, the juices would be burned up, and the seed would become shrivelled and parched. The seed is finally separated from the husks by thrashing and fanning. Though the seed is so valuable in itself, and the husks supply food of a most nutritious kind for cattle, flax growers are in many cases so blind to their own interests, that they avoid the trouble of rippling, and send the flax

Flax Rippling.

to be steeped with the bolls on, and consequently sacrifice the seed.

In the description of the flax plant given in a previous chapter, it was stated that the stem was composed of a woody core encased in fibre, the two being closely united by a glutinous substance. The first process in preparing the flax for the manufacturer is one whereby the adhesion between the parts is dissolved, and the separation of the fibre made possible. According to carvings in their tombs and temples, it would appear that the early Egyptians accomplished this in the way still preferred by the flax growers of Europe—namely, by steeping the flax straw in water. Many attempts have been made to improve on this method of extracting the fibre, but the results so far have not been satisfactory. By the use of chemicals, some inventors have endeavoured to reduce the time required for steeping, while others have aimed at the same end by heating the water used; others, again, have sought to get out the fibre without wetting the straw. The odour given off by the decay of the soluble parts of the plant is very offensive, and that is perhaps one of the strongest objections to steeping, or "retting," as it is technically designated. The Belgians have long been famous for their successful treatment of flax at this stage, and the system of steeping practised in the Courtrai district is believed to be the best known. It is thus described by Mr. Warden: "The flax is placed perpendicularly into wooden crates or frames, about 12 feet long, 8 wide, and 3 deep, tied up in small sheaves bound with bands. It is packed close together, the sheaves standing on the butt end, which prevents any damage to the top. The flax is well covered with straw, and the crates are then launched into the river Lys, and kept under the water with large stones. It is never allowed to sink to the bottom of the river, because the mud would damage the fibre; and the nearer it is kept to the top of the water, the better, as the heat of the weather quickens the process. When the necessary change has taken place, which is known by the woody part pulling out of the fibre for 6 or 8 inches, the crates are hauled on shore, where the flax is unpacked and carted to the grass. The sheaves are then placed on the butt end to dry; and after this is thoroughly done, which it will be in two or three days, if the weather be favourable, they are ready for stacking. The process of bleaching or stacking is performed by the farmer at his leisure, but March is a favourable month for this operation. Steeping is a regular trade to many men, and two or more unite in the possession of a number of crates, adapted to a given expanse of water, for which they pay no rent, and the Government protects them from the interference of shipping. For many miles along both banks of this celebrated river the steeping process is conducted, and farmers send their flax long distances—in some cases forty miles by land—to be steeped. Stacking the flax for some time after it is steeped is said to enhance the value, particularly with respect to colour." This mode of steeping has been tried in various parts of Ireland, but only to a limited extent, as the fishings in the rivers are too valuable to be sacrificed to the interests of the flax producers. Visitors to the flax-growing districts must have observed at frequent intervals along the banks of the streams pits of various sizes, but none having a depth of more than from 3 to 4 feet. These are the "lint holes," in which the flax is steeped just as it used to be in the earliest days of the linen manufacture in Ireland. When the steeping is in progress, the stench that arises from the pits is exceedingly offensive, and makes itself apparent over a wide area. The pits are filled with water some time before the flax is put in, so that the fluid may be softened by the action of the sun and air. Into each pit one layer of sheaves is put, in a slightly inclined position, and with the roots downward. A covering of straw, or rushes, and then one of sods, is placed over the flax, and stones are used to keep the whole under water. In about eight days after depositing the flax in the pits, it will be found on examination that the glutinous matter which binds the fibre and the core together has been almost, if not quite, dissolved. Should the operation be complete, the flax is removed from the water without delay; but it sometimes happens that, owing to the hardness of the water, or the low temperature prevailing, steeping for twelve or even fourteen days is necessary. As it is important that the flax should be taken out of the water as soon as possible after the desired change has taken place, the persons in charge of the pits test a few straws at intervals. Having ascertained that the retting is complete, they either allow the water to run off, or they enter the pits and lift the sheaves carefully out of the water. The first of these modes of proceeding is strongly condemned, as it not only pollutes the rivers, but wastes what is really a valuable manure. Another objection is that the water in running off leaves behind it and draws into the midst of the flax all the mud and scum that may have accumulated in the pit. Mr. Charley says: "The only proper way of taking out the flax is to

make the men stand in the water, for then the bundles are washed and cleansed in lifting out, and the liquid can be kept in the pools till spread over the meadows; or, if not thus used, it can be run off into the streams during the first flood or fresh, at which time its presence would scarcely be felt or remarked." On being removed from the water, the sheaves are set on end and allowed to drain for about twenty-four hours. The flax is then carried to the meadows, where the sheaves are unbound, and the straw laid out in a thin layer on the grass. Exposure to the air in this way bleaches the fibre, and also renders its separation more easy. Six to eight days if the weather be showery, or ten to twelve if it be dry, is sufficient on the grass, the straw being during that time turned over several times, in order that it may be equally bleached. When sufficiently "grassed," the flax is gathered again into sheaves, and stacked ready for scutching.

Of the many plans tried as substitutes for the steeping process, one or two which gave promise of satisfactory results may be mentioned. A Belfast gentleman named O'Reilly suggested, seventy years ago, that the separation of the fibre might be accomplished by boiling the straw in pure water, or, if it were desirable to hurry the process, in a caustic lye. An alternative proposal made by him was to suspend the flax in a steam-tight chamber, with a boiler attached from which steam was to be introduced. For many years these suggestions appear to have passed unheeded; but, at length, somewhat similar ideas occurred to two inventors, who gave them practical shape. The first of these was Mr. Shenck, whose patent retting process found high favour about twenty-five or thirty years ago. His plan was to construct pits lined with wood or cement, with a coil of perforated piping on the floor of each. The flax was deposited in these, water was allowed to flow in, and then, by turning steam into the pipe, the bath was raised to a temperature of 80° to 90° Fahr. So rapidly was fermentation induced, that usually about 60 hours sufficed to complete the retting. The fibre of flax treated in this way was regarded as being nearly equal in quality with that obtained in the ordinary way; but the expense of the process was considered to outweigh any advantage it offered over the old mode of steeping, and it gradually went out of favour. Mr. Watt, of Belfast, sought to improve on Shenck's process, by subjecting the flax to the action of steam. The straw to be operated upon was placed in a close iron chamber, and the steam was admitted through a pipe in the bottom, and forced its way among the stalks until it reached the roof, where it was condensed, and in that form dropped upon and thoroughly saturated the flax. After being subjected to this treatment for from 12 to 18 hours, the flax was taken out and immediately passed between heavy iron rollers, which pressed out the moisture and detached the fibre from the woody parts. The flax, having been dried in a steam-heated room, was ready for the scutchers. The following advantages were claimed for Mr. Watt's process:—Saving of time, economy of fibre, avoidance of nuisance, and beneficial application of waste products. The prejudice—if we may call it so—in favour of steeping in the old-fashioned way was, however, too strong to admit of the general adoption of the system, which, it was alleged, produced fibre that was deficient in both spinning and bleaching qualities as compared with that treated by steeping. With the oldest and most successful flax spinners it has always been an article of faith that without fermentation it is impossible to develop the best qualities of the fibre, so that any process in which that is dispensed with is certain to be coldly received. The question of cheapness has also to be considered, and as yet no plan has been proposed for the extraction of the fibre that can, in that respect, at all compare with steeping.

Much interest was excited among flax growers and manufacturers, in the early years of this century, by a flax-preparing process patented by Mr. James Lee, of London. The chief object of the inventor was to get rid of the steeping process, and he produced a series of machines which separated the fibre without wetting. The machines through which the flax was successively passed were known as a threshing machine, a breaking machine, a cleansing machine, and a refining machine; and to these was added a mode of bleaching the fibre before being spun. So promising did the plan appear at first sight, that the inventor succeeded in getting it recognised as a national boon. By a special act of Parliament, the specification was ordered to be deposited in the Court of Chancery, and kept secret from the public for fifteen months, and then to be produced only by the Lord Chancellor. Mr. Lee also had the time for the completion of his specification extended from six months to seven years. He brought his invention under the notice of the Irish Linen Board, who regarded it with high favour, and negotiations were opened for their purchasing the patent rights—the price mentioned by Mr. Lee being £100,000 down, and £30,000 a

year during the endurance of the patent. Lured by the reception thus given to the new machinery, a number of manufacturers procured sets, and applied themselves to the accumulation of that wealth which they were assured waited upon all who would but abandon the old mode of treating flax and adopt the new. It was not long, however, before they found that they had been captivated by, to use the words of one of them, "a dazzling but illusory experiment." The quantity of fibre which Mr. Lee's machines turned out was so absurdly small in comparison with the cost and bulk of his apparatus, and the fibre so unfit, by its shortness, for spinning, that all who engaged in the new enterprise came to the conclusion that they had made a grand mistake. The consequence was that Mr. Lee's invention was abandoned, in the face of the patentee's assertion that if the linen manufacturers of Ireland did not accept his offer, their trade would go to England. At a meeting of linen merchants of Belfast and Lisburn, held on the 27th of February, 1816, it was agreed to present a memorial to the Linen Board with reference to Mr. Lee's invention, and the encouragement which the Board had given to it. Prior to the date of Mr. Lee's patent, the preparation of flax without steeping had been attempted in various Continental countries, but without success. A manufacturer in Rotterdam, on hearing of the trial of Mr. Lee's machines, wrote to a friend in Belfast:—"As to what you wrote me of the manner of breaking flax by machines, without water rotting or dew rotting, I presume you will soon repent of that invention; we have tried it long since, but the linen made of it was of no lasting strength."

In some parts of Russia and Germany, and also in the United States, "dew retting" is substituted for steeping. When the flax is pulled, it is spread on grass fields and exposed to the weather for from 20 to 30 days, when it is found that the action of the dew and rain has dissolved the glutinous binding of the plant. Mr. Warden says:—"Flax prepared in this way is very apt to heat when exposed to moisture, and when kept in a close place with little fresh air. The fibre, however, is soft and silky, and well adapted for spinning into small sizes of yarn, and it requires a shorter time for bleaching, and therefore it is largely used. It is very doubtful if the quality be so good as it would have been if it had undergone the usual process of steeping in water instead of exposure to the action of the atmosphere, the sun, and the nightly dews and rain." Referring to the same subject, another high authority says:—"The want of the steeping is a vital defect, not easily remedied, even by prolonged exposure to the powerful rays of the sun and the mellowing influence of the nightly dew." Dew retting was at one time practised both in England and Ireland, but never appears to have been much in favour. Some German flax growers, in dealing with the finer qualities of straw, steep it in a warm mixture of milk and water, which is said to produce valuable results.

At the Exhibition of 1851, specimens of flax were shown which had been prepared by a process invented by the Chevalier Claussen. The samples attracted a good deal of attention, and to inexperienced eyes appeared to be a great improvement on flax prepared in the ordinary way. After being rippled, the straw was passed through a machine called a breaker, by which it was crushed and softened. It was then steeped in a succession of caustic and other solutions, which detached and bleached the fibre simultaneously. A series of six vats were required for the steeping, the first of which contained a solution of carbonate of soda; the second, a weak solution of sulphuric acid; the third, soda again; the fourth, a solution of chloride of lime and sulphate of magnesia; the fifth, diluted sulphuric acid; and the sixth, pure water. The flax was placed in a wooden cage, and by means of over-head tackle lifted from one bath to the other in succession. Having been thoroughly dried, the flax was cut into very short lengths by means of a machine somewhat resembling a chaff-cutter. The inventor's idea was to "cottonise" the flax fibre, and fit it for being worked on cotton machinery. He persevered with his experiments for some time; but received little or no encouragement from flax manufacturers, who failed to see any advantage in reducing the valuable fibre of flax to the quality of cotton. The yarn made from the "flax cotton" was found to be very inferior in strength and evenness, and its production was abandoned. The jury of the Exhibition did not offer any observations on the Chevalier's invention, as it had not got beyond the experimental stage, and they did not wish to say anything to discourage further trials. The practical men among them, however, were anything but favourably impressed by the new process and its products.

It would appear that the idea of "cottonising" flax did not originate with the Chevalier; for it is on record that several French inventors made experiments with a similar object more than a century ago.

COTTON.—V.

INVENTION OF THE SPINNING-MULE—THE STORY OF CROMPTON'S LIFE.

By David Bremner, Author of "The Industries of Scotland."

GREAT as was the impetus given to the cotton manufacture by the inventions of Hargreaves and Arkwright, it was far surpassed by that which resulted from the invention of the spinning-mule by Crompton. Mr. French, in his biography of the inventor of the mule, says:—"During the period from the years 1771 to 1781—which may be called the era of the jenny and the water frame, both of these machines being matured and in full operation—the increased consumption of cotton wool was 76 per cent.; while from 1781 to 1791, the era of the infancy of the mule, the increase was 320 per cent." As the mule was advanced to perfection, the trade made enormous strides. Our imports of cotton wool rose from 6,766,613 lb. in 1780 (the year in which the mule was presented to the nation by the inventor) to 32,288,186 lb. in 1791; 56,000,000 lb. in 1800, and 132,500,000 lb. in 1810. Now our consumption is more than ten times the latter quantity. Not only did the manufacture undergo rapid extension by the introduction of the mule, but its character was changed. All attempts to imitate the muslins of India had failed, in consequence of the spinners being unable to make suitable yarn; but it was found that the mule was capable of producing yarn of the requisite degree of fineness and firmness, and immediately weavers in various parts of the country applied themselves to the task of rivalling the work of the Hindoo "tanty." They were not long in achieving complete success, and in establishing one of the most important branches of the cotton manufacture. It will naturally be concluded by those who are not familiar with the history of the man whose genius so largely contributed to the development of our national industry, that his own fortune at least was assured, and that he received some worthy recognition of his enterprise from a grateful country. Such, however, was not the case, and the story of Samuel Crompton will ever remain a blot upon the well-earned reputation of the English people for justice and generosity.

Portrait and Autograph of Samuel Crompton.

Samuel Crompton was born in the year 1753, at Firwood, a small estate near Bolton, which had been in the occupation of the family for several generations. His father, who died while Samuel was quite a child, was a man of some mechanical genius, though not identified with anything that his son accomplished. Like most children of his class, Samuel was early set to acquire a knowledge of the art of weaving at the domestic loom, and to that occupation his days were devoted, while his evenings were spent at a school in Bolton, where he applied himself chiefly to studying mathematics. When he was about sixteen years of age, he procured one of Hargreaves' spinning-jennies, on which he spun the yarn he required for his loom. Thus, alternately spinning and weaving, he passed the next five years of his life. The family had left Firwood before the elder Crompton's death, and now occupied a portion of an ancient mansion known as Hall-in-the-Wood; and in the solitude of his work room in the quaint old place, Samuel had abundant opportunity for meditation. When he was twenty-one years of age, he began to consider the possibility of

constructing a spinning machine that would produce a finer and harder yarn than could be made in the jenny. He had heard of the experiments made in spinning by means of rollers, but was not aware of the details of Arkwright's machine. In his first attempts to realise his idea, he used only one pair of rollers, believing that the pressure of these would be sufficient to elongate the roving, and control its passage to the spindles. Finding this would not suit, he added another pair of rollers, and, by adjusting the two pairs at different speeds, caused them to draw out the roving to the required degree of fineness. This was exactly what Paul first and Arkwright subsequently had done, and it is remarkable that it should have been accomplished by one who it is alleged had no knowledge of the inventions of either of these mechanicians, beyond a vague hint that some part of the spinning was done by the agency of rollers. Crompton's experimental machines were mostly made of wood, by the aid of a few tools which had belonged to his father. For five years he devoted every spare hour and spare shilling to the working out of the problem he had set to himself. When some parts of the machine were in progress, he sacrificed even his hours of rest to the work. At these times, says his biographer, "strange and unaccountable sounds were heard in the old Hall at most untimely hours; lights were seen in unusual places; and a rumour became current that the place was haunted. Samuel was, however, soon discovered to be himself the embodied spirit, which had caused much fear and trouble to his family. Even when relieved from the alarm of a ghost, they yet found that they had among them a *conjuror!* for such was the term applied in contempt to inventors in those days, and indeed for long afterwards." He had all but completed his first spinning machine, in 1779, when the spinners and weavers of the Blackburn districts made their short-sighted raid upon the carding and spinning machines which had been introduced by various manufacturers. Fearing a visit from the disorderly mob, who had wrecked a building a short distance from Hall-in-the-Wood, Crompton hastily pulled his machine to pieces and stowed it away in an attic, access to which was gained by a secret trap-door. When peace was restored, he put the machine together again, and soon afterwards demonstrated its complete practicability. Meantime, he had married an amiable young woman, who enjoyed a high reputation as a spinner on the jenny.

Having produced a small quantity of yarn on his new wheel, Crompton submitted it to the trade, who at once recognised its superior quality. The young couple determined to keep the machine a secret, and work it solely for their own advantage; but this they found it impossible to do. The demand for the new yarn was infinitely greater than they could supply; and soon the Hall was invaded by manufacturers from far and near, who competed with each other for the possession of the produce of the "muslin-wheel," as it now came to be called, in consequence of the yarn being suitable for the manufacture of the famed Indian fabric. Admission to the house was strictly forbidden, and all sorts of stratagems were resorted to with a view to worming out the secret of the young inventor. Ladders were placed against the windows of his working room, and on these prying people crowded all day long; but to little purpose, as a screen shut off the machine from their gaze. It is stated that an inquisitive person got access to the cock-loft, and spent several days in watching the operation of the wheel through a gimlet-hole! Arkwright is said to have been among those who paid surreptitious visits to the old Hall. So persistent and annoying did the conduct of the prying crowd become, that Crompton was driven almost to despair. "A few months," he says in a paper that he wrote, "reduced me to the cruel necessity either of destroying my machine altogether, or giving it up to the public. To destroy it I could not think of; to give up that which I had laboured at so long was cruel. I had no patent, nor the means of puchasing one. In preference to destroying it, I gave it to the public." In taking this step, he yielded to the selfish counsels and deceitful promises of some neighbouring manufacturers, who led him to believe that if he put his invention at the disposal of the public, he would reap a rich reward in the form of subscriptions in recognition of the gift. An agreement surrendering the machine was drawn up by Crompton, and to it about sixty firms affixed their names as subscribers of a guinea each, and about half that number as subscribers of half a guinea each. The agreement was in these words:—"We, whose names are hereto subscribed, have agreed to give, and do hereby promise to pay, unto Samuel Crompton, at the Hall-in-the-Wood, near Bolton, the several sums opposite to our names, as a reward for his improvement in spinning. Several of the principal tradesmen in Manchester, Bolton, &c., having seen his new machine, approve of it, and are of opinion that it would be of the greatest public utility to make it generally known, to which end a contribution is desired from every well-wisher of

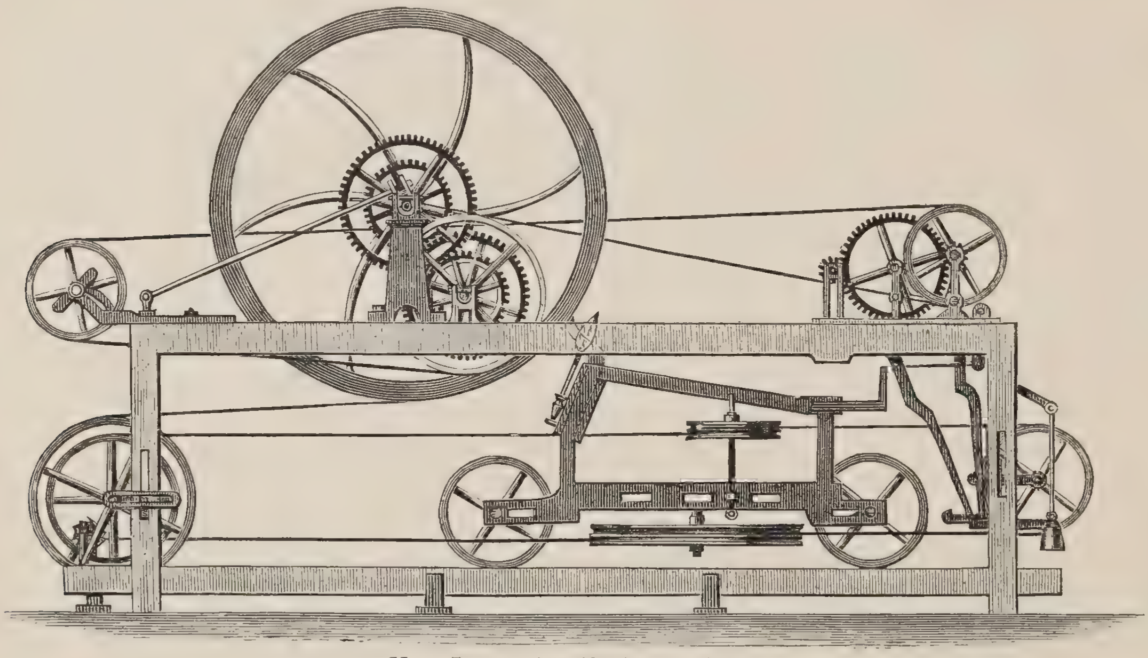
the trade." In accordance with this, Crompton handed over his original machine, and it was eagerly copied; but no sooner had he let it go out of his possession than the subscriptions ceased, and some even of those persons who had set their names to the agreement took a mean advantage of the inventor's simplicity of character, and refused to pay the trifling sum they had promised. The money obtained barely enabled Crompton to replace the forty-eight spindle machine he had given up by one of fifty-four spindles. As the machine was an embodiment of the principles of both Hargreaves' spinning-jenny, and Arkwright's water frame, it was called the spinning-mule, and that name it retains to this day.

An extraordinary impetus was, as already remarked, given to the cotton manufacture by Crompton's invention. Having, at length, found a suitable yarn, weavers in England, Scotland, and Ireland turned their attention to the production of muslins, and soon drove the muslins of India out of the market. The directors of the East India Company, in their report for the year 1793, explain the falling off in their revenue by stating that "every shop offers British muslins for sale, equal in appearance, and of more elegant patterns, than those of India, for one-fourth, or, perhaps, more than one-third less in price." The demand for mule yarn became so great, and the prices paid for spinning it were so high, that many artisans, such as carpenters, shoemakers, hatters, and smiths, relinquished their occupations and became cotton spinners. The mules spun only from rovings, and these were prepared on some of Arkwright's machines, and also on the "slubbing-billy," by a separate set of work-people. The muslin weavers of Bolton shared largely in the prosperity of the time. They received four guineas for weaving a piece of six-quarter wide muslin, with 120 picks to the inch. "The trade," we are told, "was that of a gentleman. The weavers brought home their work in top-boots and ruffled shirts, carried a cane, and in some cases took a coach." The frolics they indulged in remind one of the later freaks of the successful gold-miners of California and Australia. Among other follies was the wearing of £5 notes on their hats; and such superior creatures did they regard themselves to be, that they resented the intrusion into the rooms of the public-houses they frequented of persons belonging to any other craft.

It is deplorable to think that while hundreds of manufacturers were reaping fortunes, and thousands of work-people were earning higher wages than they ever did before, the author of this prosperity, smarting under the slights and injustice to which he had been subjected, was toiling for a livelihood at his own mule, in the upper room of the farm-house of Oldhams, to which he had removed. So expert a spinner had he become, however, that his yarns were finer than anybody else could produce, and brought the highest price in the market. In consequence of these facts, an impression prevailed that Crompton had effected some improvement in his machine, and his house was besieged by persons eager to discover what was going on. Such was the persistent curiosity of the intruders, that the inventor had to protect his apparatus by means of a secret fastening attached to the door of his work room. The first Sir Robert Peel (then untitled) was among the visitors to Oldhams who endeavoured to get a peep into the mysterious chamber. Mr. Peel, on the same occasion, offered to Crompton a partnership in his extensive manufacturing business; but the latter had conceived a dislike to the future baronet, owing to the shabby manner in which he behaved in the matter of the mule presented to the public, and declined the offer. It appears that in the exercise of a privilege secured by a contribution of one guinea to the Crompton compensation fund, Mr. Peel called upon the inventor to inspect the new machine. He took with him several mechanics, who were to study the mule so as to be able to carry away its details in their minds; and when they had completed their inspection, Mr. Peel offered to reward Crompton for his trouble by a payment of sixpence a head for his mechanics. This was too much for Crompton's sense of dignity, and he never could forgive what he regarded as a deliberate insult. It was unfortunate that such an incident should have occurred to prevent Crompton's acceptance of an offer which would have at once raised him into a position of comparative independence, and afforded him opportunities for the further exercise of his mechanical genius. As it was, he elected to continue spinning at home on his own account. But here, again, he soon found himself beset with difficulties. In order to carry on business on a remunerative scale, he required to engage assistants; but as soon as these became proficient spinners, they were decoyed away by his wealthy competitors, and he was always left with "green hands." This treatment, coupled with that to which he had been previously subjected, exasperated the sensitive nature of Crompton to such an extent that he broke up his spinning machines, and betook himself once more to the occupation of weaving. When this

crisis occurred, many men were accumulating large fortunes by the use of the mule; and Sir Richard Arkwright, whose claims as an inventor were not so well established as Crompton's, was living in the enjoyment of great wealth as the result of his labours in the development of the cotton manufacture.

Having recovered in spirits to some extent, Crompton removed into Bolton in 1791, and established a small factory, in which he employed his two elder sons. One of the sons informed Mr. French that among his earliest recollections were his "being placed, when seven years of age, upon a stool to spread cotton upon a breaker preparatory to spinning, an elder brother turning the wheel to put the machine in motion." Again the superior quality of Crompton's yarns attracted notice, and again he was subjected to the annoyance of having his work-people decoyed from his service after they had acquired the art of spinning. Thus matters went on for several years, in the course of which Mrs. Crompton died, and left her husband with a family of eight. At length, in the year 1800, it occurred to some Manchester manufacturers that the man who had been the chief agent in creating the industrial prosperity of which their city was a chief partaker, had been treated in a rather discreditable manner; and they undertook to promote a subscription, which they expected would enable Crompton to pass the remainder of his days in comfort, and without the necessity for further toil as a cotton spinner. The time was ill-chosen, however, as trade was in a very unsatisfactory state, the crops had failed, and disturbing events were in progress on the Continent. The result was that the money subscribed to the Crompton fund amounted to only between £400 and £500. This, however, enabled the recipient to extend his factory, and increase his returns. He could not help, however, giving way at times to feelings of disappointment; and in one of these moods he applied to the Society of Arts, with the object of getting the members of that institution to interest themselves in his case, and procure him redress. In his letter he mentioned that, besides his spinning machine, he had "lately invented a loom of a curious construction, in which he weaves an article that other weavers cannot execute, which stimulates the master manufacturers and weavers to endeavour, by all unfair means, to get acquainted with his machinery." After four years' deliberation, the Society adopted a resolution to the effect that the object of Mr. Crompton's letter "did not come within the views of the Society." This decision he felt very keenly, as he understood that the Society had been founded specially to give advice and assistance in such cases as his.



MULE JENNY. (*Specification Drawing*).

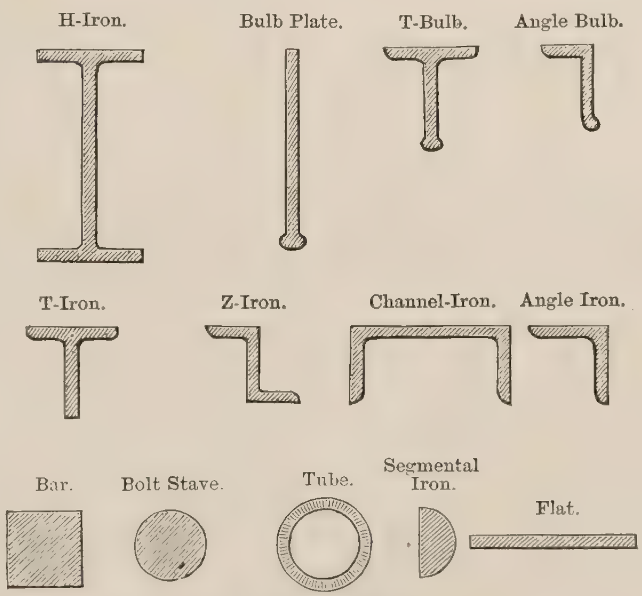
Curious to know to what extent his invention had been taken advantage of by cotton manufacturers, Crompton set out in the autumn of 1811 to visit the chief seats of the trade throughout the kingdom. He found the mule at work in

360 factories. The number of spindles used upon Hargreaves' jenny machines was 155,880; upon Arkwright's water frames, 310,516; and upon Crompton's mules, 4,600,000. Mr. French mentions, among other facts ascertained, that the mules were spinning at the rate of forty million pounds weight of cotton wool per annum; that double the amount of wages was paid for spinning on the mule that was paid for working all other spinning machines put together; that about two-thirds of the entire amount of steam power employed in cotton spinning was then applied to turning Crompton's mule spindles; that at least four-fifths of the cotton cloth bleached in the principal bleach works in Lancashire was woven from yarn spun on mules; that the value of buildings, power, and machinery employed in spinning on Crompton's system was between three and four millions sterling; that 70,000 persons were directly employed in spinning on mules; 150,000 more in weaving the yarn thus spun; and that, at the usual computation of two others dependent on each worker, the aggregate number of persons whose livelihood was provided for by the mule (without including the large addition of those who were engaged in making machinery, growing cotton, transporting it, dyeing, printing, embroidering, and selling) was little short of 700,000. In this statement no account is taken of the large numbers of mules which had been successfully introduced into the woollen factories of the country. As the result, most probably, of the manner in which the early years of his life were spent, Crompton was always of a retiring and modest disposition; and when, during the journey of investigation referred to, the manufacturers of Glasgow desired to give him a complimentary banquet, he failed to summon sufficient courage to accept the honour; and he used to relate that, "rather than *face up*, I first hid myself, and then fairly bolted from the city."

SHIP BUILDING.—VI.

THE STRUCTURAL ARRANGEMENTS OF IRON SHIPS.

IN determining upon the most suitable structural arrangements for a ship, the builder obviously has no easy task. His choice must be largely influenced by the material to be employed—wood, iron, or steel; and even when this selection has been made, every step onwards involves careful consideration, if the best results are to be attained. Enormous strength must be provided in a structure which will have to withstand the fury of wind and waves, to be driven at high speeds in all weathers, to carry weights at least equal to its own weight, and often much greater than its own, and to sustain variations of strain such as are never brought upon any structure erected upon land. Moreover, it is absolutely necessary that this strength should be associated with the least possible weight of material. A ship afloat, and displacing a certain weight of water, can only have her total weight of hull and cargo equal to this weight of water displaced. Any increase in the weight of hull, therefore, leads to a diminished cargo-carrying power; while conversely any saving on the weight of hull adds to the commercially remunerative carrying power. The whole art of ship building may be summed up in the phrase—How best to associate strength with lightness. It may, of course, be said that the civil engineer or the architect displays his skill most fully in a similar association of the maximum of strength with the minimum of material; but it is certain that these workers are not bound to



SECTIONS OF BAR IRON.

follow out this policy by the same urgent considerations which influence the ship builder, nor is their task so difficult. The grand structures due to their genius are stationary, with foundations resting upon the solid earth. The maximum strains which are brought upon these structures are calculable, and can be provided against with a reasonable margin for safety. When once a good foundation has been secured, all the subsequent work can be advanced with a degree of exactness and certainty, as to the provision of the necessary strength, which cannot be rivalled in ship building. And no one complains if additional weights of materials are employed to make the assurance of safety "doubly sure." Contrast these conditions with those for a ship—say a steamer, propelled by powerful machinery. Who can predict the vicissitudes of weather to which she may be exposed? Who can estimate the violence of the shocks she has to sustain in a sea-way? Who can measure the changes occurring in the magnitude and character of the strains sustained by her structure? At one instant perched high on a wave crest, with bow and stern in mid-air: a few seconds later with bow deep-buried in the wave slope, or astride a wave hollow. Rolling heavily, pitching deeply, heaving up and down with the waves, but all the while advancing steadily on her course, and carrying safely her precious freight of passengers and cargo, such a vessel undoubtedly represents one of the greatest triumphs of human skill and enterprise. Scientific investigation, unaided by experience, could never have produced such a result; experiments could never be arranged to represent these varying conditions; but the wisdom and experience obtained during many centuries, touched in recent times by the hand of modern invention and scientific analysis, have yielded these remarkable results, and promise to yield others no less remarkable.

The development of steam navigation has been accompanied by a great increase in the sizes of ships, their lengths, and the ratios of length to breadth. All these changes have been favourable to the attainment of higher speeds and more regular ocean passages; but they have also produced a considerable increase in the strains to which the structures of ships are subjected. The structural arrangements which sufficed in the ships of the early part of this century have consequently become quite insufficient. Then a vessel 200 feet long was a marvel of size, and her beam would have been quite *one-fourth* of her length: now, vessels 500 feet long are at work in the merchant service, the beam being only *one-eleventh* of the length. In 1838 the *Great Western* well deserved her name: she was only 210 feet long, and a wooden hull gave her sufficient strength; but no wooden hull would suffice for her successors on the trans-Atlantic service. In short, the use of iron hulls became a necessity for ocean steamers, because wood hulls could not be made strong enough; and although iron will, in its turn, probably give place to steel before many years have passed, this change will not take place because the limit has been reached to which the strength of iron hulls can be carried, but because steel is stronger than iron in proportion to its weight. Good qualities of iron used in ship building have a tensile strength of about 20 tons per square inch, and each cubic foot weighs 480 pounds; whereas the steel now used has a tensile strength of about 30 tons, and a weight per cubic foot of 490 to 500 pounds. In their main characteristics and adaptability for ship construction, iron and steel may be fairly classed together. Both of these materials are far better suited than wood for use in structures which are subjected to great and rapid variations of strain. Both can be produced by the manufacturer in varied forms, meeting the requirements of the builder, and both can be wrought into combinations possessing practical rigidity of form, with the capability of resisting tensile, compressive, or torsional strains.

Wrought iron used in ship building may be arranged in two groups—plate iron and bar iron. Every one knows what is meant by an iron plate; and all that need be said about this class of iron is that the makers are continually increasing the dimensions of the plates that can be produced. In exceptional cases, plates 24 feet long and nearly 6 feet wide have been furnished to the builder, the cost having risen with the dimensions. Ordinarily, plates about half as long and half as broad would meet all requirements. Except for defensive purposes in war ships, the thicknesses of plates used in ship building would not exceed 1 inch, and they diminish by differences of $\frac{1}{16}$th of an inch down to $\frac{1}{4}$ inch in thickness. Armour plating is a special manufacture, and single plates have been made no less than 22 or 24 inches in thickness, weighing from 25 to 30 tons. Twenty years ago an armour plate $4\frac{1}{2}$ inches thick and 3 tons in weight, was considered to be a remarkable production. The limit of progress in iron manufacture has not yet been reached, and it is a matter for congratulation that past experience with iron will be of

great value in steel making and rolling, when the demand for the latter material becomes more widespread.

In the sectional forms of "bar" iron, the ship builder now has a very extensive choice, and in the diagram (p. 181) a few of the chief sections are shown. That most commonly used is also the oldest—the simple "angle iron," which at first formed the only means of stiffening the iron plating of boilers or ships. When two plates are placed at right angles to one another, or at some other inclination, the angle iron forms an efficient connection between them; and, in association with plate iron, angle iron can be used to form beams or girders of great strength. Although it thus holds the first place, the angle iron is now frequently replaced as a stiffener by the T-iron, the Z-iron, or the channel iron, shown in the diagram. The sections in the upper line are chiefly used for deck beams or girders; and in them we have an illustration of the tendency in the iron manufacture to produce finished sectional forms resembling those previously made up of plates and angle irons. Much work of a preparatory character is thus saved to the ship builder, who has, however, to pay a higher price to the iron maker for the improved section. As an example, take the T-bulb beam in the diagram; formerly this section was necessarily made up of a "bulb plate" with two angle irons riveted to the upper edge, and even now the difference in cost leads many builders to continue the old method of construction. Another case in point is that of the H-iron section, which can now be obtained from the manufacturer by any builder who does not object to its cost; but which is really an improvement upon the earlier beam, formed of a vertical web plate, with two angle irons riveted to each of its edges. A third example is found in the Z-iron, which even now is often formed by placing two angle irons back to back, and riveting them together. In fact, where a stiffener requires to have considerable curvature given to it, the Z-iron or H-iron sections can only be obtained by combinations of plates and angle irons; because, if produced in a single piece in the rolling mills, neither of these sections could be bent without considerable difficulty or possible damage. The "flanged" form of section illustrated in several of the sections on the diagram is pre-eminently adapted for associating strength with lightness; and it is not one which can be successfully imitated in wood. The sectional forms shown on the lower line in the diagram require only a few remarks. Square and round bars are used for forgings, pillars to decks, &c.; the tubular form is also largely used for pillars; and the remaining sections are useful for some minor purposes.

Plates and bars of iron are the forms in which that material comes into the hands of the builder, whose duty it is to combine them as efficiently as possible into a strong and light hull. Taking the case of an ordinary iron merchant ship—such as that of which the structural arrangements are illustrated on page 185—it will be interesting to notice the principal features, and their comparative efficiency.

The *skin* is an essential part of every ship. Its primary function is to form a water-tight envelope of the internal space required for accommodation and buoyancy; and in some special vessels—such as the coracle or skin-covered canoe—this is the only function of the skin. In nearly all classes of ships, however, the skin is a valuable element in the structural strength; and in no class is this so true as in iron and steel ships. When iron first came into use for canal boats, the builders naturally constructed the water-tight skins on the model of the shells of wrought-iron steam boilers; and they could not have improved upon that plan in any important particular. Minor modifications have since been made, but, on the whole, it may be said that the method of constructing the skins of iron ships which was first adopted still remains in use—a fact which is sufficient evidence of the efficiency of the plan, seeing that many attempts have been made to improve upon it.

An iron skin is made up of plates, arranged with their greatest measurement lengthwise in the ship, and placed in tiers or "strakes" from keel to gunwale. Common sizes for these plates are from 10 to 14 feet in length, and from 3 to 4 feet in breadth. Even in ships of the largest size, the thickness of the skin plating does not exceed 1 inch, and in small vessels it falls to a quarter of an inch or even less. Each tier or strake of plating, reaching from stem to stern, has to be made up of several plates; and the ends or "butts" of adjacent plates are secured by means of butt straps, one of which is shown in the accompanying diagram (Fig. 1). This strap is fitted inside the abutting plates, and secured to the end of each by iron rivets, which are first heated, then driven through holes in the strap and plates, and clenched or "knocked down" at the points. Two plates thus united can, of course, resist a considerable longitudinal strain tending to separate their butts: and the junction is also easily

made water-tight. The enlarged section in the drawing (marked "caulking of butt") illustrates the simple plan which answers admirably for the skins of iron ships and for the shells of boilers. The caulker first cuts a slight score on either side of the joint, and close to it: afterwards with a

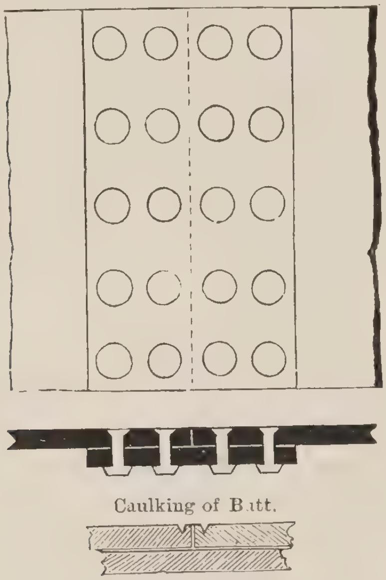


Fig. 1.—Butt Strap: Double Chain Riveting.

special tool, he forces the portions of the plates between these scores and the joint into close contact with one another, and this makes the joint either water-tight or steam-tight. A strong connection is also made between adjacent strakes of the plating by overlapping the plate-edges and riveting through the laps: as shown in the sketch (Fig. 2) of a lap joint, which also illustrates how such a joint is simply caulked (see c in enlarged section).

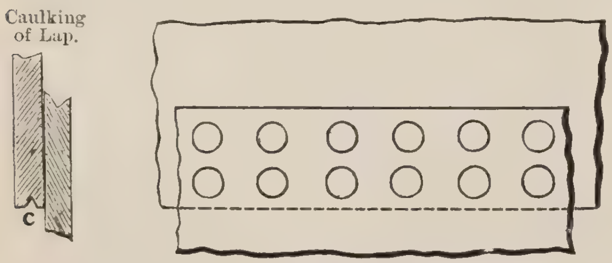


Fig. 2.—Edge Lap Joint: Double Riveting.

This edge riveting of strake to strake not merely resists any tendency to distortion in the skin by longitudinal "racking," or the motion of one strake in relation to another, but also resists any transverse strains tending to separate adjacent strakes. In fact, an iron skin, properly stiffened and kept to shape, is capable of resisting or transmitting strains in every direction. This fact is in itself a great source of superiority to the iron ship as compared with one of wood, in which the skin is relatively weak, and easily distorted by racking strains unless specially strengthened against them.

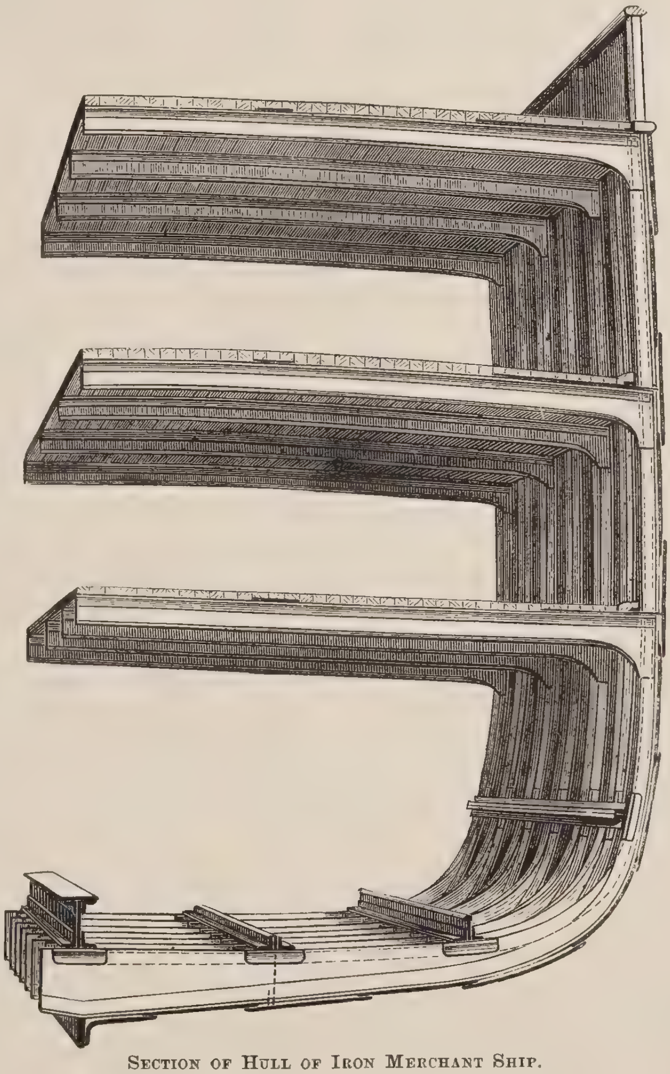
This distinctive feature of an iron skin has not always been recognised so fully as it now is; and it may be regarded as an advantage obtained rather by accident than intention, for the chief object in fitting butt straps and edge laps in earlier vessels was simply to secure water-tightness. Many persons, impressed with the belief that arrangements proved to be of value for wood ships must also be good for iron ships, have proposed to strengthen the skins of the latter by diagonal braces; or, to form the skins of two or more layers of plating placed diagonally, the plates in one layer crossing those of the others. All such proposals, however, ignore the property explained above—viz., that an iron skin, as ordinarily worked, is itself capable of resisting or transmitting strains in all directions.

Turning to the other side of the picture, mention must be made of a feature in which wood skins are superior to iron. Iron ships have thin skins, which are more easily penetrated than thicker wood planking when a vessel grounds on rocks, or is struck by sharp, hard substances. Formerly, great stress was laid upon this argument as affecting the safety of iron ships; now very little is said on the subject, and from this circumstance it may be inferred that experience with iron ships does not favour the older view. As a matter of fact, iron ships have skin plating strong enough to withstand all but the most exceptional conditions of service; and against extraordinary risks they can be protected in a

much more efficient manner than would be possible if their skins were merely thickened. Internal water-tight sub-division is the safeguard for iron ships against the dangers resulting from perforation of the bottom. Sir William Fairbairn did much to remove this stigma from iron ships by a series of experiments, designed to test the force of the then popular objection to thin skins. Taking certain planks and plates, he arranged a "punching" apparatus which measured the force required to drive a hole through each specimen tested. An iron plate only $\frac{1}{4}$ inch thick proved equal in resistance to a 3-inch oak plank, and a plate 1 inch thick was equal to a 6-inch plank. These results were highly favourable to the iron; but on the whole it may be admitted that a well-built wood ship will withstand rougher usage than an ordinary

iron ship when aground on a rocky bottom; and will not admit such large quantities of water into the hold. On the other hand, an iron ship is much more easily and cheaply repaired than a wood ship, if she can be floated off, although her bottom may have been more extensively perforated. The case of the *Great Britain* illustrates this difference. After visiting her in Dundrum Bay, Mr. Brunel wrote as follows, in 1846:—"She is resting and working upon the rocks, which have broken in at several places and forced up many parts of the bottom 12 or 18 inches;" but he added that "even within 3 feet of the damaged part there is no strain or injury whatever." No wooden ship similarly exposed would have escaped with damages that were equally local, and so easily repaired.

Against tensile and compressive strains the thin iron skin compares still more favourably with the much thicker wood skin. Take, for example, two large merchant ships of equal size: the bottom planking of the wood ship would be about 5 inches thick, against a bottom plating $\frac{3}{4}$ inch thick on the iron ship. The tensile strength of the iron would be about 20 tons per square inch of sectional area, that of the wood being about 3 to 4 tons. The difference in thicknesses is, therefore, roughly proportional to the differences in ultimate tensile strengths, the greater strength of the iron plate being a compensation for its less thickness. This would be probably true also of the ultimate resistances of the planking and plating to compressive strains. In practice, however, we are concerned with the strains that can be repeatedly brought upon a structure without distressing it, rather than with the ultimate strains which would produce rupture. From this point of view the iron gains greatly, for it can be trusted to bear a strain equal to one-fourth of its ultimate strength, whereas the corresponding strain for wood is only one-eighth or one-tenth the ultimate strength. These are facts which cannot be overlooked in contrasting the strengths of wood and iron ships, and in endeavouring to discover why the iron vessels can be made so much lighter. Each square foot of the $\frac{3}{4}$-inch iron skin would weigh 30 lb.; each square foot of the 5-inch wood skin would weigh about 20 lb. But the "working load" which the iron skin could bear would be quite *twice* as great as that for the wood skin, allowance being made for the greater thickness of the latter.



SECTION OF HULL OF IRON MERCHANT SHIP.

The operations involved in preparing the skin plating for an iron ship require only a few words of explanation. The iron maker supplies the plates very nearly to the dimensions and forms required by the builder, whose work mainly consists in marking upon each plate the positions of the rivet-holes, punching or drilling these holes, planing the butt ends so that they may fit accurately against those of adjacent plates, and bending the plates to the proper curvilinear forms. All these operations are extremely simple, but care is necessary in order to make the work sound and good. A badly-arranged and badly-riveted skin can only be a source of trouble and weakness; and faults of this kind are inexcusable, because they involve a practical negation of the advantages obtainable with a properly constructed iron skin.

Even when a ship is floating at rest in still

water, her sides and bottom are subjected to considerable pressures, tending to produce alterations in the form, and a collapse of the skin at some places, or a "bulging out" at others where heavy weights are concentrated. At sea, considerably greater straining forces have to be resisted; and the most perfectly constructed iron skin is, if left to itself, so flexible and easily distorted that some kind of internal "framing" or "stiffening" is an absolute necessity. In ordinary iron ships, as has already been explained, the main frames or ribs are placed transversely (see the drawing on the previous page); but in many ships a different mode of framing is adopted. There are, it is perhaps scarcely necessary to say, very various opinions respecting the merits of these rival methods of construction, and to some of these attention will be devoted in the following chapter.

IRON AND STEEL.—VI.

MALLEABLE IRON.

By William Dundas Scott-Moncrieff, C.E.

HITHERTO we have only spoken of iron in the form which renders it suitable for being cast first into "pigs," by the blast furnace, and next, into every variety of shape after a second melting in the cupola furnace. We now pass on to the subject of Malleable Iron, which we shall find to have been quite as much associated with the history of invention and with the lives and fortunes of inventors as the process of smelting. It is in its malleable form that this metal, so varied in its application, becomes capable of being drawn out into wires, or rolled into sheets and bars, of being bent and hammered, and hardened and softened. Although we introduced the blast furnace first, as the most natural order to take in the modern practice of the manufacture, enough has been said in the previous chapter for the reader to understand that "malleable" was far the earliest form assumed. The substitution of iron for bronze in the implements of early races, marks a distinct epoch in the development of their civilisation, and we find that among the representative nations of bygone ages, improvements in the means of producing iron and rendering it serviceable keep pace with their advances in art and all other intellectual pursuits. It is only from iron in its malleable condition that we discover any clue to these early industries, and it seems probable that nothing was known of cast iron until within the comparatively recent period of which some account has already been given in the chapter on Fuel. Among the Greeks, the introduction of iron for the useful purposes to which it has since been subjected, spread with their civilisation; and between the period of the Homeric poems, which first refer to the method of forging it, and the time when Greece had become the representative of the highest social and intellectual development of the ancient world, there is ample evidence of its having been extensively employed. There is also abundant proof of its having displaced bronze in the advancing civilisation of the Egyptians. Mr. Layard has enhanced the interest of the antiquarian collections of the British Museum by many specimens of the iron manufacture of Nineveh, the most interesting of these being tools that are still in common use—such as knives, hammers, picks, and even saws. There is one instrument of the last class which excited much curiosity at the time of its discovery, as it is almost identical with that which is in vogue at the present day, in the form known as a two-handed cross-cut saw. It was found in the North-West Palace at Nimroud, and must be more that 2,500 years old. As we have already fully discussed the earlier processes employed in the production of cast iron, we will merely say, with regard to the malleable iron of prehistoric times, that it could only have been produced from the richest ores, in small quantities at a time, and at the expense of a great amount of labour. It also seems evident that charcoal was the only form of fuel that could have been used in the primitive apparatus that was employed.

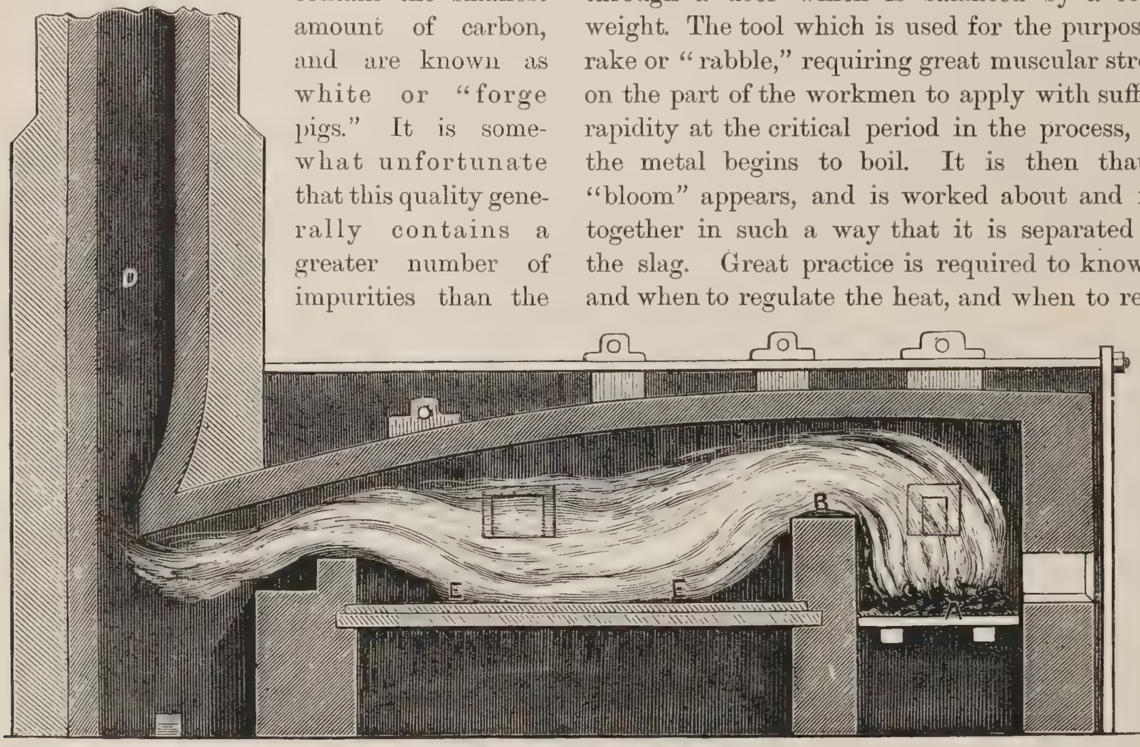
The further development of the industry must have taken place after the discovery of the manner in which combustion is increased by the application of a blast of air; and this led, no doubt, to the method employed at a very remote period, of placing the furnaces in an exposed situation, where they could be reached by the action of the winds. This gave rise to the term "air-bloomeries." In Britain, these must have been carried on, principally by the Romans, on a very extensive scale. This is proved

by the waste heaps that surrounded them, from which the iron had been only very partially extracted, having long afterwards become the mines from which more recent, but still ancient, manufacturers obtained their supplies of the raw material. It appears that gradual improvements in the construction of the apparatus used for making malleable iron, led to the products of those furnaces assuming more and more the character of cast iron, and it also seems probable that this gradually gave rise to a separation between the first operation and the second, which would always become more necessary —namely, that of refining or converting cast into wrought iron. However that may be, it is not until the year 1783–4 that we find the invention applied which really brought the method of producing malleable from pig iron into consonance with the practice of modern times.

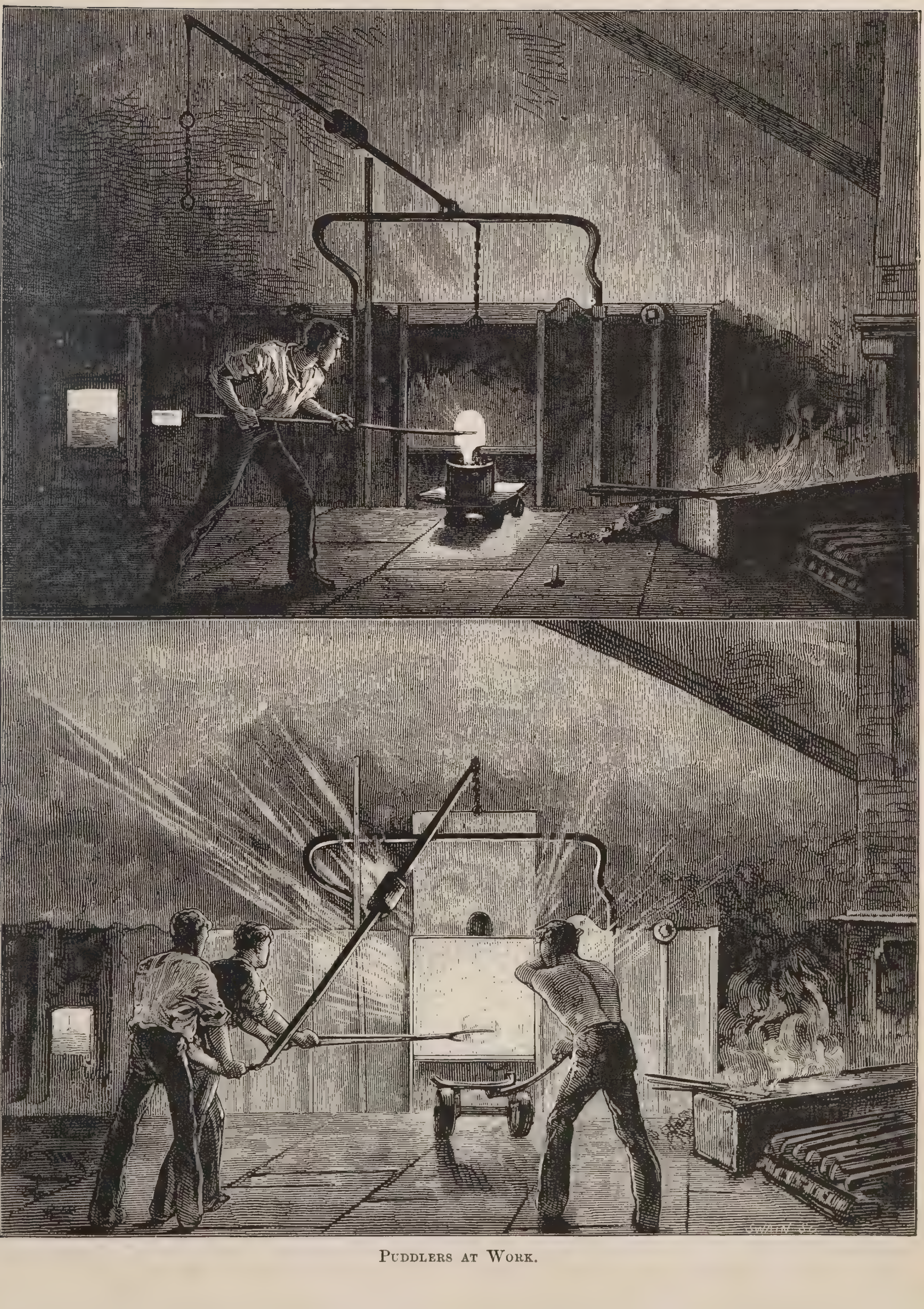
This process embodied what has since been known as "puddling," and it may be looked upon as the foundation of the iron industries of the world. It is quite impossible to estimate in figures the enormous value which has accrued to this country from the invention referred to. The discoverer spent a large fortune upon the development of his ideas; but although he entered into written agreements for the payment of royalties with several of the ironmasters of England and Wales, who afterwards amassed vast fortunes out of the new method, yet, they not only neglected to fulfil their obligations, but allowed the unfortunate genius and his family to live in beggary. There is no sadder story among the many that have occurred in the history of invention than that of poor Henry Cort. His first patent, which was obtained in 1783, described "a peculiar method and process of preparing, welding, and working various sorts of iron, and of reducing the same into *uses* by machinery, and a furnace and other apparatus adapted to the same purpose." A second patent was granted to him in 1784, for "Shingling, welding, and manufacturing iron and steel into bars, plates, rods, and otherwise, of purer quality, in larger quantities, by a more effectual application of fires and machinery, and with a greater yield, than any method before put in practice." In perfecting these new methods of manufacturing malleable iron, Cort expended a fortune of £20,000, which in those days represented much greater wealth than it does in our own. In speaking of these improvements, Sir William Fairbairn seems to consider it as proved that the introduction of the system of rolling iron into plates and bars had its origin in the genius of Henry Cort; but the process to which the country is most indebted to him is that which first enabled the manufacturer to produce wrought iron on a large scale and at a comparatively trifling cost. There is some evidence of other inventors having worked in much the same direction as Cort, in the refinement of iron in "a reverberatory furnace, heated by coal," which is the essence of the "puddling" process; but there is no doubt that he was the first to overcome the difficulties that lay in the way of its practical adoption. The description which is given in one of Cort's patents of the manner in which he proposed to treat the iron, proves from its correctness that he must have known and seen a great deal of the practice of puddling in the experiments which led up to it. The authority just referred to, in speaking of Cort, says:—"It would be a difficult task to enumerate all the services rendered by Mr. Cort to the iron industry of this country, or sufficiently to express our sympathy with the relatives and descendants of a man to whose mechanical inventions we owe so much of our national greatness. It is, perhaps, not generally known that Mr. Henry Cort expended a fortune of £20,000 in perfecting his inventions for puddling iron, and rolling it into bars and plates; that he was robbed of the fruit of his discoveries by the villany of officials in a high department of the Government, and that he was ultimately left to starve by the apathy and selfishness of an ungrateful country. When these facts are known, and it has been ascertained that Mr. Henry Cort's inventions have conferred an amount of wealth on the country equivalent to *six hundred millions sterling*, and have given employment to *six hundred thousand* of the working population of our land for the last three or four generations, we are surely justified in referring to services of such vast importance, and in advocating the principle that such substantial proofs of the nation's gratitude should be afforded to rescue from penury and want the descendants of such a benefactor." Soon after the introduction of puddling and rolling, the invention of the steam engine by James Watt gave the same impetus to the production of malleable iron that it did to the smelting of the metal in the blast furnace, to which we referred in our first chapter.

The conversion of "pig" or highly carburised iron into wrought iron, essentially consists of removing the carbon by exposing it to the action of currents of air and flame, in which the oxygen combines with it, at the same time allowing the

phosphorus and other injurious alloys to be carried away with the slag. When this is conducted on a large scale, it necessitates the employment of a great number of expensive appliances. These consist of steam hammers and other forms of noisy machinery, which, together with the din of falling plates and bars that ring upon the floors as they are removed from the rolls, make a malleable iron manufactory one of the industries which it is very difficult to describe orally on the spot, by reason of the uproar. The "pigs" that are chosen for conversion into malleable iron are those which contain the smallest amount of carbon, and are known as white or "forge pigs." It is somewhat unfortunate that this quality generally contains a greater number of impurities than the more highly carburised "foundry pigs," in which the larger quantity of carbon renders them more difficult to convert into wrought iron. Before charging the puddling furnace with the "pigs," they used generally to be put through a refining process which partially deprives them of their carbon. This consisted of subjecting the cast iron to the action of a blast of air forced over it when at a sufficiently high temperature. The methods employed in the more modern practice of the manufacture enable the cast iron to be converted directly in the reverberating or puddling furnace; but of these we shall have something to say in a future chapter. The advantages arising from the latter method are, that the iron is less subjected to contact with the impurities of the fuel, from which it is apt to absorb sulphur and other deleterious substances. The accompanying sectional sketch will sufficiently explain the construction of an ordinary puddling furnace. The peculiar shape of the arched roof brings the flame from the fireplace A over the bridge B, in such a way that the flame strikes down on the bottom E, which contains the iron that is being subjected to the decarburisation that is necessary for converting it. The waste gases escape up the tall chimney D, at the top of which there is a damper, under the control of the puddler, enabling him to regulate the force of the heat at will. The operation of stirring the iron is carried on at the side of the furnace, through a door which is balanced by a counter weight. The tool which is used for the purpose is a rake or "rabble," requiring great muscular strength on the part of the workmen to apply with sufficient rapidity at the critical period in the process, when the metal begins to boil. It is then that the "bloom" appears, and is worked about and rolled together in such a way that it is separated from the slag. Great practice is required to know how and when to regulate the heat, and when to remove the molten mass to be pounded under the steam hammer. As the carbon becomes eliminated by the action of the air, the iron becomes gradually tougher and more cohesive, and then assumes the granular appearance of large grains of tapioca. During the process the silica and other impurities become melted and pour away, while, at the same time, various substances, such as hammer scales, salt, and limestone, are thrown in, which assist the oxidising of the carbon, and form a flux that helps to remove the slag. In this manner a large ball of white-hot iron about 13 inches in diameter is obtained by collecting the small granular masses with the "rabble;" and when the lump has become sufficiently compact, it is removed from the furnace, and subjected to the action of a powerful steam hammer, which kneads it together like a mass of



SECTION OF A PUDDLING FURNACE.



Puddlers at Work.

stiff dough. There is, perhaps, no appliance which has been a more constant subject of invention than the puddling furnace. The specifications of the patents that have been taken out for improvements upon it, would fill a large volume, and it still continues to afford an ample field for further modifications. As in other industries, the great object in the production of malleable iron is to save time, labour, and material, which all bulk very largely as an element of cost in a rolling mill. It would occupy a complete and lengthy treatise to go into detail upon what has been done to bring about economy in "puddling." Some inventors have devoted their attention to saving the arduous labour of the puddler—whose work is so exhausting that it must be confined to a comparatively few years of his life—and many ingenious appliances have been invented with this object in view. The plan that has shown most promise of success—for the "puddler" is still in general requisition—is making the furnace itself revolve, so that the molten contents are kept in a constant state of agitation which exposes them to the action of the flame. The great difficulty in the successful application of a mechanical arrangement of this sort, is the very high temperature that requires to be guarded against. This is met as far as possible by covering the inside of the revolving furnaces by very "refractory" substances which protect the outside casing from the action of the intense heat. Other ingenious methods are employed for the protection of the moving parts, or bearings, by keeping cold water circulating through pipes in contact with them, so as to keep the temperature as low as possible. Considerable success has attended these efforts, but the wear and tear are so great that many manufacturers prefer to work with the more primitive appliances introduced by Henry Cort nearly a hundred years ago. Economy of fuel is another object that has hitherto afforded exercise for the ingenuity of inventors, but as this is a subject of itself, we hope to say something more about it at another time. The following is a list of the machinery required for producing finished wrought-iron plates and bars in a rolling mill such as that to which our description of the puddling process refers :—

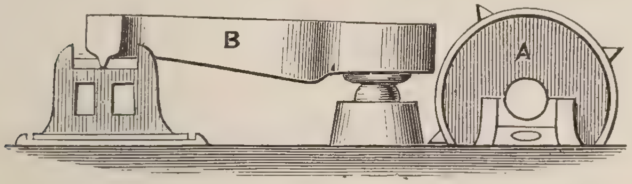
6 Steam engines of 180 total nominal horse-power.
2 Five-ton and 2 fifty-cwt. steam hammers.
3 Helve hammers.
1 Set of puddled iron rolls.
1 Set of boiler-plate rolls.
1 Merchant train and balling mill.
16 Puddling furnaces.
14 Balling and scrap furnaces.
And other machinery, such as plate and bar shears, turning lathes, &c.*

The first process to which the puddled ball of iron is subjected when it is removed from the puddling furnace is called "shingling." The effect of this upon the iron is to get rid of a good many of the impurities, such as scoriæ, which have attached themselves during the "puddling," and at the same time to make it dense and compact. Before the heat has passed off, and while the puddled mass is still pliable, it is passed between great rollers, by means of which it is drawn out into bars, that are afterwards cut into short lengths and faggoted. This last operation—the name of which has its origin, no doubt, in the analogy of a bundle of sticks —is carried out by boys, who build up small blocks of the shingled iron on a thin framing of wood, which enables them to be lifted and moved about without falling to pieces, like a pack of cards. These are then placed in what are called *balling* furnaces, which raise the faggots to a welding heat, when they are again subjected to the action of the steam hammer and a different set of rollers. The shape which the wrought iron is ultimately to assume is entirely regulated by the shape of the rolls. If, a ball previously heated until it is soft and ductile is passed through flat rolls, which are gradually screwed together more closely as the lump becomes thinner, in the course of repeated rolling, it will assume the form of a plate, the thickness of which is under the control of the workmen who regulate the width between the surfaces of the rolls. If on the other hand, bars of iron of different shapes are required, the rolls need to be grooved accordingly —a square groove producing a square bar, and a round one making a round rod. For ship-building purposes large quantities of iron are required for making the frames to which the outside plating is riveted, and these are called angle bars, because their section represents a right angle L. These are made of every variety of dimensions, both with regard to length and thickness, in the same way as the round rods or square bars, by having grooves turned in the rolls of the exact shape that is required. After the plates have come from the rolling mill, they require to have their edges trimmed and squared; and as a great variety of shapes is required in the "scantling" of the plates of an iron ship, it becomes the business of some skilled mechanic at the iron works to arrange the rolling

* This list was given to Sir William Fairbairn by Messrs. Rushton and Ecersley, of Bolton, but is, of course, greatly exceeded in many rolling mills.

of his plates so as to have as little waste as possible. He has to exercise very much the same sort of judgment as a good tailor, who cuts his cloth with a view to the utmost economy. The shears with which the plates are cut and trimmed perform their work with the greatest ease and accuracy, passing through the toughest iron as if it were so much broadcloth. In the case of bars and rods, it is only the ends that require to be trimmed, and this is generally done with a steel circular saw, which revolves at a very great velocity, and cuts through the iron as it comes hot from the rolls.

Previous to the introduction of the steam hammer there was a great variety of ingenious appliances in use for working up the "bloom" after it came from the puddling furnace; but these have nearly all been superseded by more modern and improved machinery. The accompanying sketch will show the construction of the old forge or helve



Helve Hammer.

hammer, for many years in use for the manufacture of malleable iron.

The manner in which this somewhat primitive piece of mechanism was applied was by raising the heavy mass of iron B by means of the projections upon the revolving wheel A, and then allowing it to descend upon the "bloom" as soon as the passing of the cam had relieved it. There were also different forms of squeezers adopted with the same object in view, and one of these—called the "alligator"—was a very formidable piece of apparatus indeed. Nearly all these appliances have been replaced by the steam hammer and by improved forms of rolls.

The strains to which the machinery of a rolling mill are subjected are so excessive and so sudden, that the materials require to be selected with great care, and all the working parts made of enormous strength. The reader can readily understand that when operations that depend upon the high temperature of the iron have to be conducted upon a large scale, any loss of time which allows the material to cool renders it so unmanageable that it must either break the rolls or stop the engine. It follows that this class of machinery is liable to constant accidents, and it is well worth the manufacturer's while to pay good wages for the most highly skilled workmen, in order as far as possible to avoid them. It would occupy too much space to describe all the machinery in common use in the wrought-iron trade at the present day; but the "steam hammer" has taken such an important place in the manufacture that we cannot do better than conclude this paper with a short account of it. Mr. Nasmyth, whose name has been immortalised in connection with this invention, took out his patent in 1833, and from that time it has held its own against every other form of machinery which has been designed with the same objects in view. The arrangement is essentially the same as that of an ordinary steam engine, in so far as it depends for its working upon a piston and piston rod working in a cylinder, the movements of which are regulated by means of valves that apply the steam to the under or upper sides at will. In the case of the steam hammer, as first introduced by Nasmyth, the cylinder is inverted, and supported by columns that are inclined outwards, so as to allow of the iron placed upon the anvil-block being turned about from side to side without the tongs of the smith coming into contact with the framing. The trouble arising from the columns interfering with the movements of the workmen led to an arrangement known as Rigby's, by which the steam cylinder was supported upon only one column, which is made very strong, and admits of the iron that is undergoing the process of forging being moved through an almost complete circle. Another modification of Nasmyth's hammer has come greatly into use, and was introduced by Mr. Condie. It consists of keeping the piston and piston rod stationary, and allowing the cylinder itself to rise and fall, acting the part of the hammer, which it is peculiarly well fitted to do, from the great weight which is a necessary condition of its construction. A great variety of modifications have been introduced, more especially bearing upon the valve gear, which is arranged in many cases to meet the requirements of some particular industries. In the manufacture of steel bars that are used for making into tools—such as chipping chisels, drills, &c.—a steel ingot is first heated in a furnace, and then drawn out into a long bar by the action of the steam hammer alone.

The introduction of the steam hammer has, as may be readily supposed, facilitated to a great extent many of the operations of the smithy, and immensely curtailed the labours of the blacksmith. Where forgings of the same kind are required in

large quantities, they can be produced with ease and rapidity by means of "cresses," or moulds, into which the iron is placed, being heated first to an almost welding temperature, and then subjected to the blows of the hammer. In this way the numberless appliances, such as the cleats, and hooks and eyes, and bolts of the rolling stock of our railways, are turned out at a less cost per dozen than they could be made singly by the more laborious labours of a blacksmith unaided by the steam hammer.

For some special purposes, forging machines have been invented, which work at the rate of as many as 1,000 strokes per minute, and make the screws and bolts for which they are specially designed with a rapidity that is truly astonishing. There is also special machinery for making rivets, and bolts, and nuts, which reduce their price far below the labour of the anvil. There is no one who ever had a higher appreciation of the work of our great inventors, or a more far-seeing estimate of the importance of their labours, than Sir William Fairbairn, and so we cannot do better than conclude this chapter by quoting a sentence of his on the subject of the steam hammer :—"It has given an impetus to the manufacture and affords facilities for the welding of large blocks of malleable iron that could not be accomplished by the tilt and helve hammers formerly in use; and we have only to instance the forgings of the stern posts and cut-waters of iron ships, the paddle wheels and screw shafts of our ocean steamers (some of them weighing upwards of 20 tons), to appreciate the value, as well as the intensity of action, of the steam hammer."

FOREIGN RIVALRIES.—III.

IRON MANUFACTURE.

By H. R. Fox Bourne.

Of iron ore produced in the United Kingdom, for example, during 1876, the total amount was 16,841,583 tons, valued at £6,825,705, and therefrom were extracted 6,555,997 tons of pig iron, the value of which was raised by expenditure of fuel, labour, and other essentials, to £16,062,192. Of copper ore, 79,252 tons were produced, which, after smelting, yielded 4,694 tons of copper, worth £392,300. The production of tin ore was 13,688 tons, from which 8,500 tons of refined metal, worth £675,750, were produced. From 79,096 tons of lead ore, again, 58,667 tons of lead, worth £1,270,415, were obtained. The quantities and values of zinc and other metals manufactured in our country during the same period, were comparatively small. Indeed, as the above figures show, our manufacture of iron is of far more importance than that of all other metals put together, though out of these others, in combination with iron and with one another, or separately handled, a multitude of finished articles of immense aggregate value are constructed.

Great alarm has very reasonably been caused by the rapid falling off in our iron trade during the past few years, after a period which long gave promise of unbounded growth. In 1840, less than 300,000 tons of iron of all sorts were exported from this country. In 1850, the amount had grown to about 780,000 tons. In 1860, it had reached 1,500,000; in 1870, more than 2,800,000; and in 1872, nearly 3,400,000. Since then, however, there has been a steady downfall, in value as well as in quantity, the total of 1876 being barely more than 2,224,000 tons. The decline in the home consumption of iron, moreover, following on the wonderful ascent of the previous generation, has been quite as astonishing as that of the export trade. In both cases, the decrease is partly owing to causes which, however unfortunate to our merchants and manufacturers, here hardly concern us. The enormous demands made upon them by foreign countries, not only for metal goods, but also for textile fabrics, and other commodities requiring the erection of extensive machinery to manufacture them, encouraged a state of production which the foreign markets have not continued to justify. Our Continental neighbours have, to a large extent, supplied themselves from England with the ways, steamships, docks, and other public works which they needed—having, in some cases, greatly embarrassed their finances to do so—and consequently, they come to England much less than they did a few years ago for these things or the materials for them. Political complications, and the ruinous development of rival armaments, moreover, have

offered grievous obstacles to the extension of peaceful arts, and the following of such pursuits as give an impetus to industrial enterprise. All these circumstances have seriously affected the prosperity of England without in any way benefiting other countries. There are other circumstances, however, concerning which Englishmen cannot console themselves by reflecting that they are only sharers in the general misfortune, consequent on an almost universal depression of trade. There can be no doubt that as regards many of the trades in which England has till lately had the supremacy (if not something approaching to a monopoly), a formidable rivalry has grown up abroad, and threatens to grow yet more; and in no other is this rivalry more marked than in the iron trade.

Of our foreign rivals, the United States and Germany are, perhaps, the most notable, though hitherto the most energetic competition has come from Belgium and Sweden. In 1876, Great Britain produced an average of 3·80 cwt. of pig iron per inhabitant; while the production of Belgium during the same year was at the rate of 2·01 cwt.; and that of Sweden, in 1875, the latest year for which we have returns, 1·58 cwt. The corresponding proportion in 1876 for the United States was 1·08 cwt.; for Germany, including Alsace-Lorraine, 0·96 cwt.; for France, 0·80 cwt.; and for Austria 0·28 cwt.; the yield of Russia in 1875 being at the rate of only 0·12 cwt. Gauged by quantities, however, these countries stand in a different order. The production of Great Britain being, as we have noticed, close upon 6,556,000 tons; that of the United States was 2,266,500; that of Germany, 1,862,500; that of France, 1,449,500; that of Belgium, 540,000; that of Austria, 480,000; that of Russia, 397,500, and that of Sweden only 339,500 tons. But though both these sets of figures are suggestive, neither of them adequately indicates the nature of the competition already existing, or to be looked forward to, between our own and other countries. The enterprise shown in Sweden, for instance, has hitherto been of almost unmixed advantage to England, as it has done little more than furnish our manufacturers with the finest qualities of pig iron, by which they have been greatly assisted in turning out the most finished sorts of tools and machines. Belgium, again, though it has made amazing progress in its iron industries during the past quarter of a century or so, and thereby has done temporary injury to some branches of English trade, even competing successfully with many English makers in our own country, is so scantily endowed with mineral wealth as compared with Great Britain—actually, not relatively, that is—and is so deficient, moreover, in the best varieties of ore, that the alarm with which its rapid progress has been regarded has already nearly spent itself. England may well be jealous of the economical labour arrangements and the delicacy of workmanship that exist in most of the Belgian foundries, and of the increasing importation into Belgium of the superior kinds of iron from Germany and elsewhere which might otherwise be brought to this country for manufacturing purposes; but as a producer of pig iron, its rivalry with England is never likely to be of much account. The same remarks are, in the main, applicable to France, whose iron ores are very similar to those of Belgium.

It is from wealthier and larger countries, like Germany and the United States, that the greatest danger must be looked for. In the second chapter of this series, some illustration was furnished of the rapid growth of iron industry in Westphalia, consequent on the opening up of its coal mines, and the facilities thus afforded for utilising its mineral treasures. How much further and how rapidly this growth may continue, no one can estimate; but it is noteworthy that, notwithstanding its having suffered, on the whole, quite as much as other countries from the recent depression of trade, and in spite of the obnoxious fiscal arrangements that now prevail in the country, Germany has tided over the evil period of iron manufacture more successfully than almost any of its rivals. Whereas the quantity of pig iron produced from British ores sank from 6,742,000 tons in 1872, to 6,566,000 in 1873, and to 5,991,000 in 1874, rising only to 6,365,000 in 1875; the production of German pig iron rose from 1,988,000 tons in 1872 to 2,246,000 in 1873, was 1,906,000 in 1874, and rose again to 2,029,000 in 1875; the supplies of the manufacturers of iron and steel for the same four years being 2,087,000 tons, 2,108,000 tons, 2,246,000 tons, and 2,098,000 tons. It is true that of these quantities larger proportions were each year exported to be further manufactured by more skilful operatives, and under abler superintendence than Germany itself could afford, the rise as regards all sorts of iron and steel being from 260,000 tons in 1872, to 613,000 tons in 1875; and the inference to be drawn from this fact is strengthened by some competent critics. "In former times," says Vice-Consul Kruge, in his Report to the Colonial Office for 1877, "German industry was able to compete successfully, at least in what may be called cheap

goods, with that of other countries, because she had the advantage of cheap and good labour. This advantage has been entirely lost since the last war. Immediately after the war, German manufactories were completely overwhelmed with orders. This was an opportunity not to be lost sight of; but, instead of trying to secure all such new customers, by delivering only articles of unquestionable quality, the great majority of manufacturers could not abandon their short-sighted policy for the sake of a momentary profit, and the natural consequence took place. Germany got in worse repute both at home and abroad, and the new markets were lost." Other opinions, however, are more favourable to Germany. "Of course, as a manufacturing nation," Mr. A. J. Wilson points out, in his work on "The Resources of Foreign Countries," "Germany is at present far behind us; being immeasurably poorer, more heavily burdened in ways that tell on the efficiency of labour, and far from thoroughly organised; but these disadvantages will narrow as time goes on, unless the trade legislation of the Empire follows a mistaken course, and, by taking the retaliatory and *quid pro quo* line, effectually stops for an indefinite period all progress in this direction."

In the United States, yet more than in Germany, mischievous legislation, intended for the protection of native industry, is a serious hindrance to its healthy growth. It has undoubtedly given an artificial stimulus to the trade in many districts, but already the result of that hot-bed development is apparent. "In 1870," wrote Mr. Lowthian Bell, in January, 1877, "the production of pig iron was under 2,000,000 tons, in 1873 it was nearly one half more, and by the end of 1875 the power of the furnaces in existence, as claimed by the iron-masters themselves, was almost exactly three times the quantity it was in the first-named year, the increase being equal to nearly 25 per cent. on the entire make of the world. It was expected that immediate employment would fall to the share of the new furnaces by the exclusion of the 1,000,000 tons formerly supplied by Great Britain, and so far as imports are concerned, the hope has all but been fulfilled. American consumption, however, has fallen off to the extent of one-half the quantity formerly imported; more than half of all the furnaces are idle, and a great number of those in blast are losing money, with pig iron considerably dearer than it was with a large importation of British iron to meet it in the market." The American iron trade has advanced mightily since 1810, when its entire production of raw metal was only 54,000 tons; and it may be regarded as still in its infancy. The source of all its past and future prosperity, however, must be found, not in a short-sighted protective policy, but in the abundant and excellent mineral stores of the country and the enterprise of its people.

In the manufacture of iron, more than in most other industries, success depends on the skill shown in making the best use of the special conditions under which the work is carried on. Not only are there infinite varieties of iron ore, each charged with its own proportion of foreign associates, some of them, like manganese and silicon, more or less favourable to the production of good and serviceable iron—or at any rate, harmless—and others, like sulphur and phosphorus, very baneful and very difficult to separate from the pure metal; but also nearly each kind of ore requires a peculiar sort of fuel to purify it—some varieties of fuel being positively injurious to certain ores, while they can be safely used with others. Hence, each country, and often each district, has to discover its own best mode of dealing with its special ores; and it is by no means easy to institute a comparison between the processes adopted in various localities. Some of the most ancient, and, as an English iron-master might consider, obsolete processes, like the clay-boxes employed in the East Indies and the primitive Catalan forge, are still found more convenient than any others among civilised and scientific workmen; and often fuel, not itself the most suitable, has to be employed because it is the best within easy reach of the ore; but, as might be expected, there has generally been a good deal of blundering from too servile imitation of existing methods, admirable where they were first adopted, in places for which they are unfitted. The increased competition of recent years, however, and the spread of scientific research, has effected a considerable change, and now we find that, if in most foreign iron fields free use has been made of the pioneer experience of England, the foreign iron workers have adopted many expedients of their own, some of which Englishmen may study with profit. Thus, while the example set by Sweden in smelting its pig iron in small charcoal furnaces—a process quite out of the question in England—has been successfully followed in certain parts of America, this method seems destined to give way to the altogether different anthracite process which has been devised in other parts, and which may, perhaps, be followed with advantage on this side of the Atlantic. Anthracite coal, though plentiful in South

Wales, is very little used among us for smelting purposes; nor is there any general imitation throughout Europe of the successful plan adopted at Creuzot, in France, of crushing the anthracite and mixing it with a binding coal, so as to form a very powerful coke. In the United States, where the abundance of this variety of coal makes its use very important, great ingenuity has been shown in making it serviceable. "In America," says Mr. Lowthian Bell, "chiefly by the use of blast obtained by very powerful machinery at twice the pressure of that commonly used with us, anthracite coal is almost as easily managed as is so much coke"; and Dr. Siemens gives an interesting account of his observations concerning the utilisation of anthracite in the Schuylkill district:—"The raw anthracite as it comes from the mine is raised to the top of a wooden structure, 60 or 70 feet high, in descending through which it is subjected to a series of operations of crushing, dressing, sieving, and separating of slaty admixtures, and is then delivered through separate channels into railway wagons." It was formerly thought almost impossible in England or Scotland to produce a ton of pig iron with less than three tons of coal. Now, the average is about two and a half tons. If the Americans can effect a further economy of even no more than half a ton (and they expect to do much more), their advantage over our own iron-masters will be very great. In 1876 they obtained 794,578 tons of pig by help of anthracite, 308,649 by help of charcoal, and 990,009 by the usual European process of mixing bituminous coal and coke.

Economy of fuel will probably always be the great object aimed at in smelting operations. Economy of labour, or rather the substitution of machinery for manual work as far as possible, is the great thing to be sought in puddling operations. The first important experiment in this direction was made some twenty years ago by the Dowlais Iron Company, in Glamorganshire, which spent about £20,000 on a plan for keeping the crude iron in a fluid state, in a revolving barrel of refractory material, until the operation had been completed. This device has had to be abandoned, and the improvement upon it introduced in 1871 by Mr. Samuel Danks, of Cincinnati, cannot yet be regarded as a success. No less an authority than Mr. Lowthian Bell, however, is of opinion that efforts made yet more recently in England may overcome the difficulties hitherto insurmountable, and that "there appears every reason for hoping that mechanical puddling, before long, may be generally introduced in this country." Should that be the case, the advantage would be immense, though probably, in the long-run, England would gain less than its rivals. Nearly the most laborious occupation in which a man can engage, and one which, on philanthropic and hygienic grounds, it would be very desirable to perform by machinery, puddling is an art in which Englishmen excel, mainly because it so heavily taxes the powers of human endurance. Puddlers claim, and deserve, high wages for their work, and the wages in England are about twice as high as anywhere on the Continent, the American rate alone being higher;* yet the work produced in this country is really cheaper than that of any other, by reason of the superior skill of the workmen. When mechanical devices supersede all the most trying hand labour of the puddler, we shall lose the special benefits we derive from the trained muscles and nerves of our operatives.

The same is true of all the other branches of the iron trade, and especially of steel manufacture. Our natural advantages in the possession of suitable and accessible coal beds and iron mines can only be overcome by the discovery and opening up elsewhere of mineral treasures as rich, or, as regards fuel, by the invention of some better purifying agent than coal. Our national pride in the physical strength and endurance of Englishmen, moreover, may be so well grounded that we may defy all the world to produce as hardy and successful workmen. But the gains of scientific research, or even of accidental discoveries in the region of science, cannot be so localised. In other parts of this work our readers will learn what marvellous improvements have been made during recent years in the manipulation of iron and other metals. In some instances, the deficiencies of other countries in natural advantages have led their enterprising men to strive all the more zealously, and in the end, successfully, after compensating scientific gains. In a great many, of course, England has taken the lead; but wherever the inventions have started, they have soon been open to all the world, and, whether English or foreign, have not rarely proved more beneficial to foreigners than to Englishmen. It is impossible, for instance, to estimate the relative effects upon this and other countries consequent on the great revolution in the iron trade now going on through the substitution of steel for iron, which

* In 1873, the wages of first-hand puddlers, for a day of twelve hours, averaged 16s. 4d. in the United States; 10s. in Great Britain; 5s. 6d. in Belgium; 4s. 8d. in Germany; and 4s. 6d. in Spain.

began only about 1851. Krupp, of Essen, then astonished the world by exhibiting a steel ingot weighing 2,500lb., as well as his first steel gun and other articles made of the same material. Krupp's innovations were crude and costly, but, besides being of great value to himself in vastly developing his own business, they gave a stimulus to other innovators from which wonderful results have followed. Mr. Bessemer's experiments and achievements, fruitful enough in his own hands, have been greatly improved upon by others, and now Bessemer steel threatens to become a more important article of trade than wrought iron, unless it is itself superseded by the outcome of the yet more modern Siemens-Martin process. Extensive and profitable as is the adoption of these new methods in England, they promise—or, shall we say, threaten?—to be yet more beneficial to some of our foreign rivals. If a great number of articles, formerly made of iron, can be now more cheaply made of steel, foreign enterprise appears to gain most by the change. In the United States, for example, while 541,229 tons of Bessemer steel were produced in 1874, the quantity had risen to 1,062,336 tons in 1875, and to 1,477,931 in 1876; and against about 7,000 tons of Siemens-Martin steel manufactured in 1874—the year of its introduction—must be set 9,050 in 1875, and 21,490 in 1876. In the whole business of steel-making the Americans are very successful. "At Pittsburg," says Dr. Siemens, "where pot-melting is employed on a considerable scale, plumbago pots, having nearly double the capacity of the Sheffield clay pots, are invariably used. Eighteen or twenty-four of these pots, each containing about a hundredweight of metal, are placed in a gas furnace, and each pot lasts twenty-four hours, yielding five charges during that interval. The fuel consumed amounts to one ton of small slack per ton of steel melted, which is delivered to the works at the surprisingly low price of 30 cents per ton." At Sheffield, from two and a half to three tons of Durham coal are consumed in the like process. The growth of the steel trade in Belgium is smaller, though hardly less rapid. In 1864, the country had only one Bessemer converter, which produced 296 tons of Bessemer steel, worth £7,072. The yield in 1874 was 36,584 tons, worth £461,498, and in 1876, 71,758 tons, worth, notwithstanding the great reduction in price, £592,730. Supplying its own lack of suitable ore by importations from the neighbouring iron fields of Germany, Belgium may succeed in further developing this trade very greatly. An example of its enterprise may be seen in the fact that in 1876 the Cockerills of Seraing leased for twelve years certain Government works in Hungary, to erect steel works capable of turning out 150,000 tons of steel rails in the first year, and double that quantity afterwards. Their obtaining such a contract as this, which, till lately, would have been considered almost the prerogative of an English firm, was due to a new rail mill erected by them, and surpassed only by some works in America.

These illustrations, which we have not space to amplify, may suffice to show what dangers are in the way of England's continued supremacy as an iron-manufacturing nation. It is true that the development of the trade in most parts of Europe, though hardly in the United States, is largely due to the investment in them of English capital, for the use of which there are no facilities at home, and that thus our country gets back a share of the profits of the enterprises; but, however beneficial these operations may be, they show that a great change is imminent in the position of England, which formerly considered itself to be almost the only great manufacturing nation in the world.

About the manufacture of other metals indigenous to our country, very little need be said here. Though the native supply of tin appears to be steadily falling off, it is more than compensated for by the increased importation of the metal in a crude state; and, as it is now most largely used in the preparation of tin plate and brass, England may expect to be at great advantage in working it up as long as it is foremost in the trade in those two commodities. The deficiencies in the home production of lead and zinc ores are also more than made up for by the importation of those metals, which, besides being applied to miscellaneous uses, are also, like tin, extensively employed in combination with copper for the manufacture of brass. In the working up of copper, England has almost a monopoly. Not only is it found expedient to send nearly all the ore extracted in Cornwall and other parts of our own country to the Swansea district—which has special advantages for the delicate and complicated processes of refining it—but a very large proportion of all the ore extracted in South Africa, British North America, Spain, Italy, and elsewhere, is dealt with in the same way. England has not at present much to fear from the rivalry of foreign countries in the manufacture of these metals. With gold and silver—which can hardly be considered English metals—it is different.

Hall-in-the-Wood, where Crompton invented Mule Spinning.

COTTON.—VI.

CROMPTON'S REWARD—THE SLUBBING-BILLY—THE SELF-ACTING MULE—RICHARD ROBERTS.

By David Bremner, Author of "The Industries of Scotland."

When Crompton returned from his visit to the manufacturing districts, and made a statement as to the extent to which his invention was being employed, he succeeded in awakening fresh interest in his case, and was encouraged to present a memorial to Parliament, in which he claimed some national recognition of the services he had rendered to the country by the invention of the spinning mule. In February, 1812, he proceeded to London, and laid his case before Mr. Spencer Perceval, the Chancellor of the Exchequer, who gave him a kind reception, and undertook to present his memorial to the House. The petition was referred to a committee, who, after inquiring into the merits of the case, reported that the petitioner appeared to them to be deserving of a national reward. On the 11th of May, Crompton went to the House of Commons, as it was understood that on that day the Chancellor of the Exchequer would bring forward a motion in favour of making him a grant from the public treasury. He was standing in the lobby with Sir Robert Peel and others, when Mr. Perceval entered, and remarked to Sir Robert that he would be glad to learn that the Government meant to propose that £20,000 should be awarded to Crompton. On observing that he was the subject of conversation, Crompton moved away, but he had not gone far before he heard the report of a pistol, and saw a rush of people to the spot he had just left. To his consternation, he learned that Mr. Perceval had been shot. By this event, the hopes so nearly realised were frustrated, and Crompton returned to his lodgings with a heavy heart. The country was at this time in a very unsettled state. Through the war with France trade had received a serious check, and from various causes the prices of provisions rose to such an extent that many of the working population of Lancashire and Yorkshire suffered severely. Political disaffection ensued, and mobs of rioters rose in several quarters, destroyed mills

and machinery to a large amount, and murdered a number of persons. It became evident to Crompton's friends that the time was not favourable for his claim receiving the consideration it deserved. Still, it was determined to press forward with it. On the 24th of June, Lord Stanley moved "that a sum not exceeding £5,000 be granted to Mr. Crompton for his invention." The motion was agreed to without dissent. Crompton's idea was that his gift to the nation would have been worth £50,000 if he had kept it in his own hands, and he, as well as many of his friends, was grievously disappointed on receiving what Mr. M'Culloch, in his "British Empire," describes as "a pittance hardly adequate to defray the expenses of the application." Crompton spent five months in London in connection with obtaining the award, and the outlay during that time, and also on his journey through the manufacturing districts, was considerable, while, in addition, he had to pay the expenses of the witnesses he brought to London to establish his claim.

Writing to a friend with reference to the award, Crompton said:—"It always appeared to me that the leading men in the Government did not consider the *case*, but the *man*, who, they ventured to suppose, had never had command of a thousand pounds, which is a sad mistake, or they would never have said, 'Give him £100 a year—it will be as much as he can drink.' But I have one comfort, that I have told it often to them (after the case was made out), that me they could not dishonour; all the risk lay with themselves; and when I saw they were determined to go in their own way, I felt extremely sorry that I had ever come forward and given them an opportunity of dishonouring themselves." The art of war would appear at that time to have been held in greater honour than the arts of peace, for on the same night that Crompton's petition was presented to the House of Commons, Earl Grosvenor suggested with favour in the House of Lords that £50,000 should be invested in trustees for the purpose of purchasing freehold property to descend to the heirs of the Duke of Wellington. Mr. Palmer, of Bath, the originator of the system of stage coaches for the carriage of the mails, was a much more fortunate man than his contemporary, Crompton, as he was rewarded from first to last by the payment of £160,000 in consideration of his services to the State. In company with two of his sons, Crompton, soon after receiving the Government grant, added calico bleaching to his other business; but the venture did not prove a successful one, and was abandoned. His family had, meantime, taken to various pursuits, and he was left alone with the small spinning and weaving business which he had established in Bolton. He devoted much attention to the weaving of fancy muslins, and displayed great ingenuity in the production of new patterns. Anything novel from his loom was eagerly watched for by his unscrupulous competitors, who possessed the power of imitation, though not of invention. At this time we find him writing in the following vein:—"To this day, though it is more than thirty years since my first machine was shown to the public, I am hunted and watched with as much never-ceasing care as if I was the most notorious villain that ever disgraced the human form; and I do affirm that if I were to go to a smithy to get a common nail made, if opportunity offered to the bystanders, they would examine it most minutely, to see if it was anything but a nail."

Though his own country treated him with so much indifference, Crompton's genius had attracted attention in other parts of Europe, and manufacturers from Austria, Switzerland, and France sought him out, and personally tried to induce him to leave England and exercise his inventive faculties in promoting the manufactures of their countries, where, they severally assured him, his services should not go unrewarded. His answer always was, that he could not bring himself to think so ill of his native country, with all its faults, as to prefer any other offered to him in exchange. Old age came on apace, and with it Crompton's fortunes did not mend. His returns from the little factory dwindled down and down, until at length the originator of the untold wealth and activity that filled a large district of the country, sank into absolute poverty. At this crisis a few Bolton gentlemen came to his rescue, and succeeded in raising a fund sufficient to secure an annuity of £63. They also had his portrait engraved, and the receipts from the sale of it were designed to go for his benefit. "But," says Mr. French, "the benefit must have been small indeed, as very few copies were disposed of. Probably the manufacturing public of Lancashire disliked to see the face of a man whom they could not look upon without painful recollections of the neglect and ingratitude of which too many of them had been guilty."

Mr. Huskisson, in addressing the House of Commons, on the 25th of March, 1825, with reference to the consolidated customs duties, touched upon the marvellous progress of the cotton trade, and the speech attracted so much notice throughout the

country, that some of Crompton's friends thought the moment opportune for again bringing his case before Parliament. Mr. J. Brown, of Bolton, took a leading part in the movement, and made the nature of Crompton's claim apparent in a pamphlet entitled, "The Basis of Mr. Samuel Crompton's claim to a second remuneration from Parliament for his discovery of the mule spinning machine." In May, 1825, a memorial addressed to the Lords of the Treasury and the President of the Board of Trade was drawn up, and received the signatures of nearly all the machine makers and manufacturers in Bolton. The memorial does not, however, appear to have been presented. At all events, no additional award was obtained for Crompton, whose embittered life terminated on the 26th of June, 1827. The plain slab which covers his grave in the parish churchyard of Bolton, bears the inscription:—"Beneath this stone are interred the mortal remains of Samuel Crompton, of Bolton, late of Hall-i'-th'-Wood, in the township of Tong, inventor of the spinning machine called the mule; who departed this life the 26th day of June, 1827, aged seventy-two years." A statue of Crompton was a few years ago erected at Bolton by public subscription.

A machine, which played an important part in the early days of the cotton manufacture, and proved a valuable auxiliary to the spinning machinery of Arkwright and Crompton, was the "slubbing-billy." It was devised by a mechanic named Stockport, of Manchester, and its purpose was to unite the short lengths of carded wool produced on the stock or cylinder cards, and convert them into rovings. In general appearance it bore some resemblance to the spinning-jenny; and it is only useful to describe it here for the purpose of marking a stage in the remarkable history of cotton-spinning machinery. The billy consisted of an oblong frame which gave support to the working parts of the machine. These consisted of an endless feed apron which travelled over rollers, and a carriage on which were placed the spindles for the formation of the roving. The "card ends," as the lengths of carded wool were called, were placed on the apron by one operative, and another worked the machine. As the cardings were carried forward by the apron, they passed between a pair of rollers, and thence between a pair of clasps. When a portion of the cardings, sufficient for one "draw," had been passed out, the clasps were closed, and the carriage with its spindles, to which the respective cardings had been already attached, was slowly withdrawn, the spindles meantime revolving, and imparting to the soft sliver of wool an amount of twist sufficient to fit it for the operation of the mule. After being drawn out to the full extent, the carriage was pushed towards the apron again, and during its progress the lengths of roving formed were wound upon the spindles. A fresh supply of cardings was then let out, and drawn and twisted in the same way. The spinner pushed forward and withdrew the carriage with his left hand, while with the right he turned a wheel which gave motion to the spindles. The weights seen at one end of the machine, and the lever under it, constitute a simple but highly ingenious arrangement for moving the apron, and carrying forward the required length of cardings at the proper moment. The person who fed the machine with cardings joined the ends of the respective lengths by slightly twisting them between the finger and thumb. The spindles were turned by a series of cords passed over a tin cylinder extending across the lower part of the carriage, and set in motion by a belt from the wheel turned by the spinner. The rovings were evenly dispersed over the length of the spindles by means of a wire which extended across the machine, and by depressing or raising which the winding was controlled. The machine was improved by successive inventors, but was at length superseded by the roving machinery that formed part of Arkwright's system.

Crompton's mule had not been long in use before attempts were made by various persons to improve upon it, and considerable ingenuity was displayed in this direction. By the introduction of metal rollers and accurately made wheel-work, the quality of the yarn was much improved, and by building machines containing over a hundred spindles each the production was greatly increased.

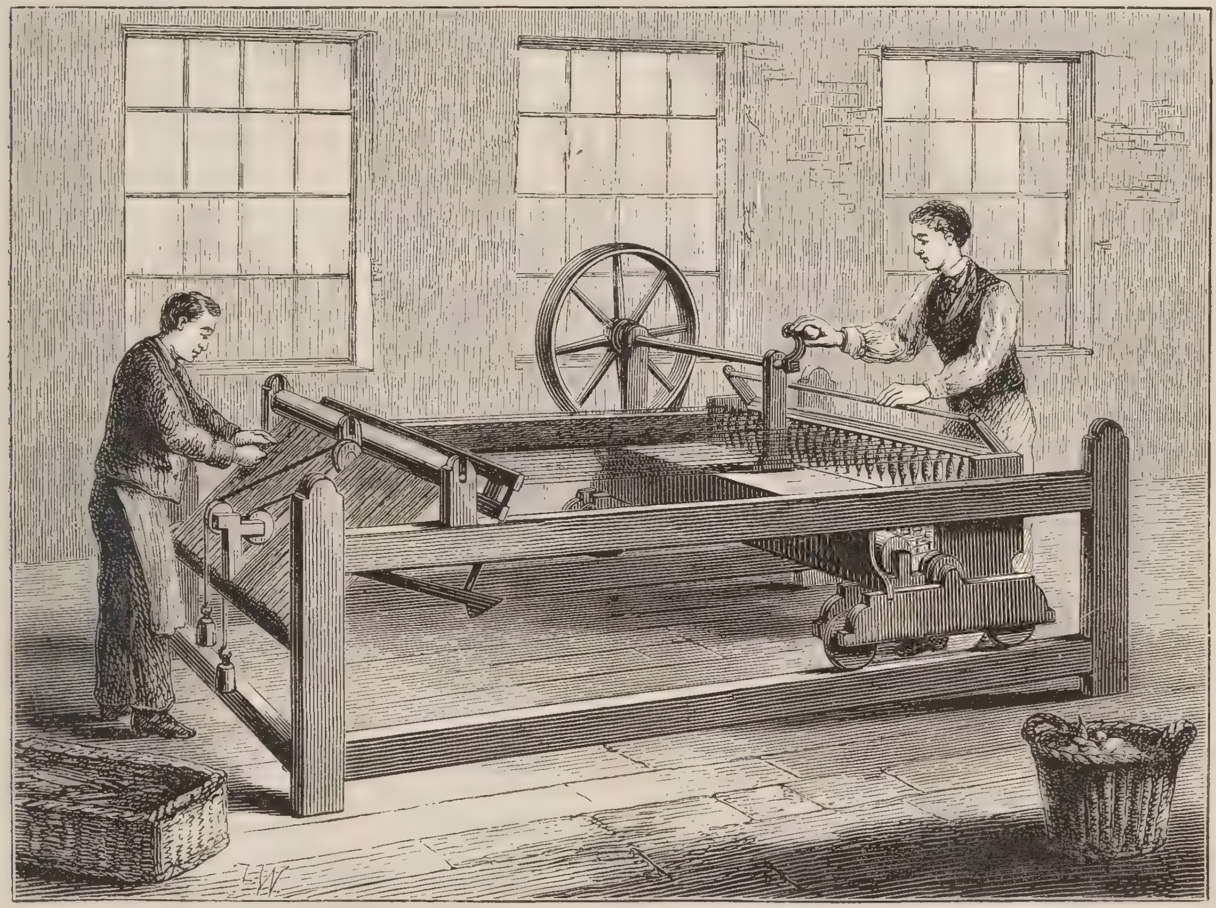
From the account of these improvements given by Mr. Baines, we gather that one of the first mechanicians who attempted to render the mule more perfect was Mr. Henry Stones, of Norwich, who saw that by introducing metal in various parts where Crompton employed wood, and giving greater exactness of form to the mechanism generally, better work would be produced. Acting on this idea, he made a mule which was found capable of producing a much finer quality of yarn; and subsequently he increased the number of spindles in the machine to over a hundred. Mr. Baker, of Bury, and Mr. Hargraves, of Toddington, effected further improvements; and in the year 1790, Mr. Kelly, of the Lanark Mills successfully applied water power to the mule. This suggested a

further increase in the number of spindles, and Mr. Wright, a machine maker, of Manchester, produced a "double mule," in which 400 spindles were successfully worked. A year or two later, Mr. Kennedy, of Manchester, made certain alterations in the wheel-work of the mule, which greatly accelerated its action. Meantime, several mechanicians had set to themselves the difficult problem of making the mule a self-acting machine, and it is believed that so early as the year 1790, Mr. W. Strutt, F.R.S., of Derby, son of Mr. Jedediah Strutt, the partner of Arkwright, devised a self-acting mule, but owing to the difficulty in those days of finding workmen capable of making machines in which great nicety was required, the invention did not reach a practical issue. In 1792, Mr. Kelly, mentioned above, succeeded in making a self-acting mule, which he continued to work until the machine was superseded by others in which certain defects it possessed had been overcome. To Mr. Richard Roberts, of Manchester, however, belongs the credit of making the first perfect self-acting mule. The cotton spinners of Manchester were not quite satisfied with the mule as it existed, and urged Mr. Roberts, who was well known for his great mechanical ingenuity, to take up the machine and try to remove its defects. The firm in which Mr. Roberts was a partner was engaged at the time in devising a locomotive engine, and as that was engrossing all his time he declined to listen to the cotton spinners. At length he yielded to their entreaties, had a mule erected in the works that he might study it, and soon he was able to announce that he had succeeded in effecting various improvements. He obtained a patent for his invention in 1825, and the machine was hailed as a most important accession to the cotton mills of Lancashire. In 1830 he obtained a second patent for further improvements, and the self-acting mule now came into extensive use. The advantages secured by the machine have been enumerated as follows:—The saving of a spinner's wages to each pair of mules, piecers only being required, as one overlooker is sufficient to manage six or eight pairs of mules; and the production of a greater quantity of yarn, in the ratio of 15 to 20 per cent. The yarn possesses a more uniform degree of twist, and is not liable to be strained during the spinning, or in winding on, to form the cop; consequently, fewer threads are broken in these processes, and the yarn, from having fewer piecings, is more regular. The cops are made firmer, of better shape, and with undeviating uniformity; and, from being more regularly and firmly wound, contain from

Crompton's Grave in Bolton Churchyard.

Statue to Crompton, Bolton.

one-third to one-half more yarn than cops of equal bulk wound by hand; they are, consequently, less liable to injury in packing or in carriage, and the expense of packages and freight (when charged by measurement) is considerably reduced. From the cops being now regularly and firmly wound, combined with their superior formation, the yarn intended for warps less frequently breaks in winding or reeling; accordingly, there is a considerable saving of waste in those processes. Mr. Roberts's mule has been modified in various parts by successive inventors, but its leading principles remain untouched. Among the names of patentees of improvements in the mule, are those of Mr. Potter, of Manchester; Messrs. Higgins and Whitworth, of Salford; Mr. Montgomery, of Johnstone; Messrs. Craig and Sharp, of Glasgow; Messrs. Parr, Curtis, and Madeley, of Manchester; Messrs. Dobson and Barlow, and Messrs. P. and J. M'Gregor, of the same city. If anything in the shape of mechanism can be pronounced perfect, the mule, as now constructed, is entitled to that designation. A full description of its parts and mode of operation will be given in a subsequent paper; but, first, the processes through which the cotton has to pass before it is ready for the mule, will have to be explained and illustrated.



THE SLUBBING-BILLY.

Richard Roberts, the inventor of the self-acting mule, was a remarkable man. He began life with many disadvantages, but rose superior to them all, and achieved a high position among mechanicians. His father was a shoemaker in an obscure village in North Wales. For some reason, Richard was never sent to school, though it is believed that his father gave him a little instruction at home in letters and figures. At an early age he was sent to work in a slate quarry; subsequently he was employed on a canal boat; and later he held the position of servant to a gentleman in the neighbourhood. It was while in the last-named situation that the youth's latent genius was awakened. Richard's employer was an amateur turner, and the lad became fascinated by the lathe, seizing every opportunity of practising on it, until, at length, he became an expert turner. Having thus discovered how his natural capabilities lay, Richard

sought more congenial employment, and engaged himself to a machinist near Bolton, as a pattern-maker. Having gained experience in this, and other like occupations, he desired to improve his position by obtaining employment in some of the great work-shops of the metropolis; and with this view he, in company with two young fellow-workers, walked all the way from Manchester to London. He succeeded in obtaining work in Maudslay's famous establishment. Having acquired sufficient knowledge of his business to warrant his starting on his own account, he returned to Manchester, and, hiring a small house in Water Street, fitted up one of the bed-rooms as a work-shop. He then publicly announced that he was prepared to execute mechanical work, and "screw cutting on reasonable terms." One of his biographers, referring to this period, says:—"His fly-wheel was in the cellar, and his lathe up-stairs in a bed-room. The strap passed through the living-room of the ground floor, and the power that turned the fly-wheel was Roberts's first wife." He found abundant employment, and his fame as a producer of exact work became widely known, and his way to prosperity was assured. The invention of a gas meter, and the slide lathe, the slotting machine, and other engineering tools, secured for him a high position in the mechanical world. Business flourished apace, and ultimately Roberts became partner in one of the most important engineering firms in Manchester. Here he found full scope for his inventive powers, and it was as a member of this firm that he effected his well-known improvements on the locomotive engine, and invented the self-acting mule. Some of his leisure he devoted to scientific research, and constructed a large variety of ingenious appliances for experimental purposes. A selection of these, borrowed from the Salford Museum, was shown at the Exhibition of Scientific Instruments, at South Kensington, in 1877. The closing years of Roberts's life were spent in London, whither he removed on the cessation of his partnership with Mr. Sharp, at Manchester. In the metropolis he followed the occupation of a consulting engineer, and by his advice many important inventions were carried through preliminary difficulties to success. He died in March, 1864, in the 75th year of his age, and was buried in Kensal Green Cemetery. The funeral was a public one, at which many of the leading engineers, a large number of the deceased's Manchester friends, and of his old workmen and pupils, were present.

SHIP BUILDING.—VII.

SYSTEMS OF FRAMING FOR IRON SHIPS.

THE external form of a ship is governed by considerations connected with her extreme dimensions, speed, and carrying power; and the builder has to make the structural arrangements conform to these ruling conditions. His object is to associate the water-tight skin with such internal framing as will secure practical rigidity in the structure, under all conditions of service; and with iron or steel as his material, this object can be attained. Two principal classes of straining actions have to be considered and provided against, in order that the form of a ship may remain unaltered. First and most important are the *longitudinal* strains, tending to make a vessel bend lengthwise; and of little less importance are the *transverse* strains, tending to produce racking or distortion in the athwartship sections. Longitudinal bending results from the unequal distribution of the weight and buoyancy along the length of a ship. Near the bow and stern, where the form of a ship is made fine in order to lessen the resistance, the weights of certain portions of the length almost always exceed the buoyancy. At other parts, and usually near the middle of the length, the converse holds good, the weights of these portions being less than the corresponding buoyancy. And so, finally, the structure is subjected to a series of upward and downward pressures, which make its condition resemble that of a beam supported at a series of points, and loaded between the supports. Amongst waves this inequality in the distribution of weight and buoyancy is exaggerated by the departure of the wave-profiles from the horizontal surface of still water; and the longitudinal bending strains are still further increased by the pitching motions impressed upon a ship. In fact, scientific investigation has not succeeded hitherto in giving any quantitative measure of the maximum longitudinal strains to which a ship may be subjected, and ship builders have to proceed largely upon methods

of comparison and inference in providing for the longitudinal strength. As the lengths and proportions of ships have been increased, the cases have not been few in which weaknesses have displayed themselves; and out of the study of these cases of partial failure—the "morbid anatomy of ship building," as it has been termed—have grown some of the chief improvements in subsequent practice. Even now there is room for further progress, all the lessons of experience not having been learnt; but it will appear, as we proceed, that commercial considerations naturally have great weight with the ship builder and ship-owner. A system of construction may be theoretically perfect, yet it will not displace a cheaper but inferior mode, so long as the latter answers ordinary requirements. To these general remarks on longitudinal strains, two definitions may be added of technical terms in common use. A ship is said to "hog" when her ends drop relatively to the middle of her length; and to "sag" when the middle drops relatively to the ends. The French comprehend both changes of form under the term "arching"; and this is found also in some of the older English books on naval architecture.

The transverse strains experienced by ships are most severe when the vessels are rolling rapidly in a sea-way, and reversing their motion every few seconds. A passenger standing on the deck of an iron-built ocean steamer, and noting her behaviour, is scarcely sensible of the "racking" strains which her structure has to resist each time that the end of a "swing" is reached. There may be no indications externally of the fact; but if the same strains were brought upon a wood ship, there would be "groanings" and "creakings" of planks and timbers, and probably sensible "working," or relative motion, in some of the parts. Here also the conditions of behaviour and strain are so various, that science has not been able to give exact rules for practice; and the ship builder arranges for the transverse strength chiefly in the light of experience. Even when the vessel is floating at rest in still water, calls are made upon her transverse strength; the fluid pressures on her sides tend to force them in, those on the bottom tend to push it upward; the concentrated weights of cargo, engines, &c., tend to push it down; and in many other ways bending strains are produced. But none of these conditions compare in severity with that incidental to rolling at sea.

A ship aground may be strained very severely both in the transverse and the longitudinal sense. In fact, many vessels which have stood for years the stress of service afloat, have altogether failed when they have grounded. Not many years ago a curious case of this kind happened on the Mersey, in which an iron vessel took the ground nearly at the middle of her length; and as the tide fell, leaving her ends almost unsupported, she literally "broke in two," her skin plating being torn asunder from keel to gunwale. A similar accident happened to an iron steam-ship at the mouth of the Thames about fifteen years ago; and the facts are worth recording, because they illustrate the great ease with which the most serious damages may be repaired in an iron ship. After the vessel had been broken in two, it was decided to raise her, for which purpose a water-tight wooden partition, or "bulkhead," was built across the end of each part of the hull. As the tide rose the two parts floated, and the rent in the sides was nearly closed. When this had happened, the two parts were strongly braced together, and the vessel was floated and towed back to London, where she was placed in dock and repaired. At a comparatively moderate cost she was again made fit for service, and is probably at work now.

It may be asked, Ought not a ship to be made so strong that she could successfully resist even the exceptional strains produced by grounding? The answer given by general consent of ship builders and ship-owners is in the negative, and reasons are easily assigned for the opinion. In the first place, a very considerable addition would have to be made to the weight of hull if the necessary increase in the general strength were obtained; and this would necessitate a corresponding reduction in the carrying power, so that a heavy price would have to be paid during the whole lifetime of a ship, in order to provide for an eventuality that might never happen to her. Moreover, if the general strength required to meet these extraordinary strains could be provided, grounding must inevitably produce serious local damage, as it did in the case of the *Great Britain.* In short, as ships are built for service afloat, and not for grounding, except under favourable circumstances, it is undesirable to regulate their structural arrangements by the strains incidental to grounding. Sir William Fairbairn, it is true, maintained the opposite opinion; but no other eminent authority has agreed with him, nor did he in his own practice as a ship builder produce vessels that could withstand such a severe trial as frequently results from grounding.

Keeping in view the foregoing general principles, let us next proceed to examine the various systems of *framing* iron ships, beginning with the ordinary

merchant ship, of which a perspective drawing was given in the preceding chapter. The principal frames in such a vessel are placed transversely, and form the "ribs" of the structure. These ribs are about 21 to 24 inches apart, and are formed of plates and angle irons. Above the "bilge"—the quickly-curved portion of the section which connects the nearly vertical sides with the bottom—each rib is simply formed by riveting two angle irons together, as shown (in section) in the accompanying diagram (Fig. 1). The outer angle iron (a) is termed the "frame," and fits against the skin; the inner (b) is termed the "reversed frame," and receives the inside planking (or "ceiling") in the hold space, and between decks. Below the bilge (Fig. 2) each rib is formed of a "floor plate" (c), upon the outer edge of which the frame angle iron (a) is riveted, the reversed frame (b) being attached to the inner edge. This floor plate gradually increases in depth from the bilge towards the keel, attaining its maximum depth at the keel. In preparing each rib, the floor plate is cut and bent to its proper form, and the holes are punched in its edges to receive the rivets fastening the angle irons thereto. The frame and reversed frame are also heated and bent to their proper shapes, the holes for connecting them to each other and to the floor plate being punched. Next, the three parts of each rib are brought together, adjusted, and riveted up: not unfrequently one or two beams are also riveted to the rib, which is then ready to be hoisted into place. It will, of course, be understood that in building a ship framed on this transverse system, the frames are prepared and erected before the skin plating is fitted. In our review of the structural arrangements, an inverse order has been followed, because the skin is of primary importance.

Fig. 1.—Above the Bilge.

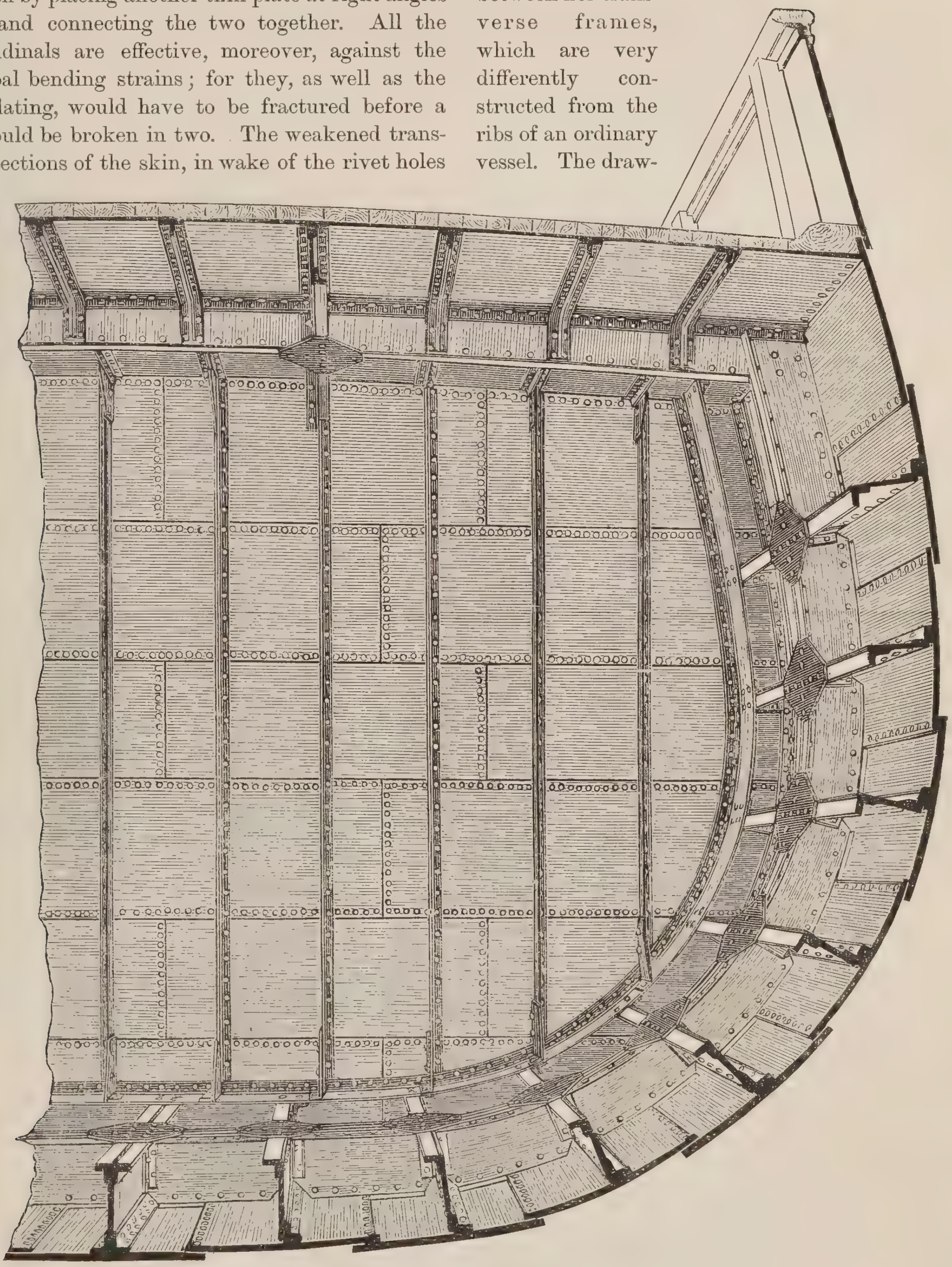
Fig. 2.—Below the Bilge.

These numerous ribs, closely associated as they are with the skin plating, give considerable transverse strength to the structure; they also afford a convenient means of attaching the deck beams to the sides of the ship. On the other hand, it will be noticed that the ribs are ineffectual in resisting longitudinal bending strains, which tend to break a ship off at some athwartship section. When fracture actually takes place, as in the cases above mentioned, the plating usually tears down through the line of rivet holes in way of one of the transverse ribs, or else diverges to some adjacent butt of the plating, and then returns to the line of holes. It is an axiom in construction that there is nothing stronger than its weakest part; and the plating through the line of rivet-holes being weaker than the plating between the frames, necessarily gives way first. Now obviously only such pieces in the framing as *cross* the line of fracture can assist the skin plating; and as the transverse ribs do not fulfil this condition, they cannot help. Framing which lies longitudinally or diagonally in the ship will cross the weakened sections of the plating, and therefore aid it in preventing longitudinal bending or cross breaking. It is an acknowledged defect of the transverse plan of framing that the principal frames—the ribs—are ineffective against the most important strains—the longitudinal. At first the matter was of little importance, the moderate dimensions of the earlier iron vessels enabling them to succeed with little longitudinal stiffening, except such as was given by the "bearers" introduced to support the engines and boilers. In subsequent practice, however, the want of greater longitudinal strength has made itself felt, and more or less numerous "keelsons," "hold stringers," &c., are now commonly fitted in iron ships. In the perspective view on page 185, the details of such strengthenings will be seen; and it will be noted that they are quite subordinated to the ribs.

This curious anomaly in common practice has been sharply criticised again and again: there have also been numerous proposals to remedy the fault, and make the longitudinal framing paramount, placing the transverse framing in a secondary place. One of the best of these *longitudinal* systems of framing is that with which the names of Mr. Brunel and Mr. Scott Russell will always be associated. It has been adopted in many mercantile vessels, received its fullest illustration in the *Great Eastern*, and, with some necessary modifications, has been made the basis of the system of construction now generally adopted in ironclad ships. A good idea of its main features will be obtained from the accompanying drawing of a transverse section of the *Annette*, and only a brief description need be added.

Each longitudinal frame consists of a girder, formed of a plate with angle irons on the inner and outer edges: it is placed near the middle of a strake of the skin plating, and strongly riveted thereto. Nothing could surpass the combination in simplicity and efficiency. The local strains tending to push the skin inwards or outwards are well met, on the same principle that a thin plate of iron, so flexible that it cannot bear its own weight without bending, may be converted into a girder of considerable

strength by placing another thin plate at right angles to it, and connecting the two together. All the longitudinals are effective, moreover, against the principal bending strains; for they, as well as the skin plating, would have to be fractured before a ship could be broken in two. The weakened transverse sections of the skin, in wake of the rivet holes which receive the fastenings of the transverse frames, are much fewer in vessels built on the longitudinal system than they are in an ordinary iron ship. Instead of having ribs 2 feet apart, the longitudinally framed ship would have 10 or 12 feet intervals between her transverse frames, which are very differently constructed from the ribs of an ordinary vessel. The drawing illustrates the arrangement: plates with angle irons on the edges are fitted between the longitudinals, so as to form a continuous transverse girder, or "partial bulk-head;" and the junctions of these partial bulk-heads with the



TRANSVERSE SECTION OF THE "ANNETTE," BUILT BY MR. SCOTT RUSSELL.

longitudinals are covered by diamond-shaped pieces of plate. In some vessels an inner skin of iron is worked upon the inside of the framing, forming a "double bottom," of the advantages of which we shall speak hereafter; when this inner skin is fitted, the diamond plates are, of course, unnecessary. Besides these partial bulk-heads, complete transverse bulk-heads are fitted at intervals, and are of great value both as contributaries to the transverse strength, and as water-tight partitions. These complete bulk-heads, formed of iron plates well stiffened by angle irons, are capable of being made practically unchangeable in form, and may be compared to the piers of a bridge. The longitudinal frames stretch from bulk-head to bulk-head, just as the girders of a bridge stretch from pier to pier; and they distribute the strength of the bulk-heads to the intervening portions of the skin. The partial bulk-heads also contribute to the transverse strength of the portions between the main bulk-heads, and assist in keeping the longitudinals to their work; but they are not always fitted. The *Great Eastern* is without them over a large part of her structure, yet displays no signs of a defect in transverse strength.

The advantages of this longitudinal system of framing are obvious; but it is not without some drawbacks, and has never found much favour in the mercantile marine. The operations of building are made more complicated, and workmen are much averse to novelty or complication; hence the cost of building such a vessel is relatively high. Greater depths being given to the frames than are usual in ordinary ships, there is a corresponding reduction in the internal space available for cargo. There is also greater liability to flexibility in the bottom plating, owing to the comparatively large areas of unsupported skin lying between the longitudinals and consecutive partial bulk-heads; while a vessel is afloat, this is of little consequence, but when she takes the ground, as a merchant ship not unfrequently has to do while lying in harbour, flexibility in the skin is objectionable. To overcome the last-mentioned objection, more numerous transverse frames have been fitted in some vessels built on the longitudinal system; and by such an arrangement the bottom can be as well stiffened as is that of a ship with ribs only 2 feet apart. The real objection to the longitudinal system undoubtedly lies in the greater difficulty and cost of the building operations, compared with those incidental to the transverse system. In the future, however, it is not unlikely that the necessities of ship construction may lead to a more extensive adoption of the longitudinal system in the mercantile marine; for it enables the capabilities of iron and steel to be most fully developed in the association of strength with lightness.

The armoured ships of the Royal Navy furnish notable examples of the truth of this statement. In their construction it is of the utmost importance to decrease the weight of hull so far as is consistent with strength and safety, in order that the weight and thickness of the armour, the power of the guns, and the speed of the ships may be made as great as possible. To these considerations are necessarily subordinated questions relating to the difficulty of building operations or the increased cost of construction; and the results obtained justify this policy. Broadly speaking, it may be said that the lower parts of the hulls are constructed on a longitudinal system, modified in some important respects from that above described. The longitudinal framing still occupies the first place: there are the complete and partial bulk-heads, the latter being about 20 feet apart; an inner skin is also fitted, forming a water-tight double bottom. A most important difference is made, however, in the amount of support given to the bottom plating, and this will be understood clearly from the accompanying sectional drawing (Fig. 3). Between the partial bulk-heads, and at intervals of 4 feet, "bracket frames" are fitted, like that shown in the diagram.

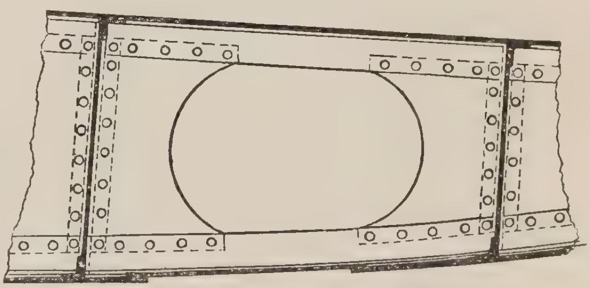


Fig. 3.--Bracket Frame.

These frames consist of an outer angle iron, which is riveted to the bottom plating, an inner angle iron riveted to the inner skin, and two brackets fitted between these angle irons, the ends of the brackets being attached to the longitudinal frames by short angle irons. With a comparatively small expenditure of weight, a most valuable addition is thus given to the stiffening of the skin plating and the longitudinals. In a vessel built on the ordinary longitudinal system, spaces of unsupported bottom plating may be found having an area of 40 or 50 square feet: with the bracket frames the corresponding spaces have not half that area. Good evidence of the excellence of this system of construction,

which was originated by the Constructive Department of the Royal Navy, is found in the fact that it has been adopted by the ship builders of all other countries for the hulls of ironclad war ships. Even the French, from whom British ship builders have learnt so much, have in this respect been glad to follow our example. These remarks apply specially to the lower parts of the hulls of the ironclads: the arrangements of the upper parts of the structure, upon which the armour is carried, will receive attention in a subsequent chapter.

A third system of framing has been carried out in a few iron ships, and is known as the *diagonal* system. The main frames are placed obliquely, instead of being vertical or longitudinal, the intention of this arrangement being to prevent the occurrence of those weakened sections of the outside plating passing through the lines of rivet holes connecting the skin to the ribs of an ordinary ship, or the bulk-heads of a longitudinally framed ship. As the lines of rivet holes in the diagonal system define sections of greater length and strength than the corresponding lines in either of the other two systems, it is supposed that fracture could not be produced except by greater longitudinal strains. So far as the skin alone is concerned, this may be true; but when the joint action of the skin and the framing is considered, it will be obvious that the longitudinal system may, with a given weight of material, be made to yield greater strength than the diagonal system. The latter involves considerable difficulties in construction, and has never found favour with ship builders. It has almost dropped out of notice, but is here mentioned because of the ingenuity of the idea upon which it is based. It is possible that the same idea may occur to other persons interested in the progress of iron ship building; and they may be glad to know that practical effect has already been given to it, and the reasons for its failure to displace the ordinary system of framing.

INDUSTRIAL LEGISLATION.—IV.

SHORT-TIME AGITATION IN YORKSHIRE—THE BILL OF 1831—ITS REJECTION AND RE-INTRODUCTION IN 1832.

BY JAMES HENDERSON, ONE OF H.M. ASSISTANT-INSPECTORS OF FACTORIES.

OASTLER'S letter in the *Leeds Mercury* produced a remarkable effect in the textile manufacturing districts. Hitherto the agitation for legislative restrictions upon the employment of young children had been almost exclusively limited to Lancashire. The cotton factories had been first complained of in respect to the cruelties and overwork forced upon young children. This, no doubt, arose from the fact that the cotton manufacture had developed much more rapidly in the country than any other branch of our textile industry. The general introduction of steam power, and the improvements made upon the machinery employed in the processes of cotton spinning and weaving, admitted of the employment of a much larger proportion of children and young persons than in the woollen and worsted trades. The Legislature had recognised this by distinctly refusing to allow any of the Acts passed for the regulation of children's employment to apply to any but cotton factories. Neither Sir Robert Peel in 1819, nor Sir John Cam Hobhouse in 1825, could overcome the objection entertained by the House of Commons to a Factory Act which would apply to all the textile manufactures alike. Mr. Oastler took the field as an agitator on behalf of the factory children at a very important juncture. The woollen and worsted trades in Yorkshire had by this time assumed such proportions, and what has come to be known as the factory system of employment had become so general and widespread, that there was really no excuse whatever for treating these branches of manufacture differently from the cotton trade. The Lancashire operatives, however, were well-nigh worn out and exhausted in the struggle to obtain anything like a really efficient law, which would check the abuses of which they so justly complained. The great difficulties that they had encountered in getting the Act of 1825 passed, and the necessity forced upon Sir John Hobhouse of mutilating the Bill so seriously, were felt to be very disheartening. The Manchester Committee, Mr. Philip Grant says, was almost on the point of breaking up, when by accident Mr. Oastler's letter was brought under their notice. The prospect of having the aid and assistance of the people of Yorkshire gave them renewed strength and courage, and in 1831 the agitation for an improved Factory Bill was renewed with an energy and determination

which had never before been equalled. On the 15th of February of that year, Sir John Cam Hobhouse introduced another measure, repealing all the existing laws affecting the employment of children in factories, and establishing a more general and more efficient code of regulations, which would apply to all textile factories alike. He proposed to limit the hours of work in such establishments, in the case of all young persons under the age of eighteen years, to eleven and a half in the day for the first five days of the week, and to eight and a half on Saturdays. An allowance of at least one hour for dinner and half an hour for breakfast was also provided for; while the employment of any child under nine years of age, in any description of factory labour, was absolutely forbidden. This Bill, it was proposed by its promoter, should apply to all cotton, woollen, worsted, and silk factories, and also to power-loom weavers. It also proposed to prohibit the employment of any person in a factory during the night who was under twenty-one years of age. Sir John, when introducing his Bill to the House of Commons, expressed his satisfaction at the change of feeling which had been manifested by many of the employers on the subject of the regulation of children's employment in factories. The Bill which he had first proposed in Parliament had been strenuously opposed, he said, by many of the most respectable master manufacturers, but he now knew, both from private sources and from the petitions which had been presented to the House, that in making the proposals set forth in his new Bill he was sustained by the opinion of a large number of the employers, who were deeply interested in the trade, and who were good judges of what was likely to promote and encourage it. Sir John also pointed out the injustice which was inflicted upon the respectable employer who conformed with the existing law by the imperfect and inefficient manner in which it was carried out. Parliament, he maintained, ought to interfere without hesitation, and put an end to the practice of working young persons during the night—a practice which was in itself fraught with many evils, and which exposed the respectable and law-abiding manufacturer to a most unfair competition.

This Bill, however, was the source of a great controversy in the textile manufacturing districts. It was highly approved of by the work-people, who were most earnest and persevering in their agitation in its favour. Meetings were held in the chief towns of Lancashire and Yorkshire, and in Nottingham, Macclesfield, Leek, and other places in which the silk manufacture was carried on, and resolutions were adopted approving of the proposals made in Sir John Cam Hobhouse's Bill, and thanking that gentleman and Lord Morpeth, the seconder of the measure, for their exertions in the House of Commons. Meanwhile, however, the employers were not idle, and a powerful opposition was organised by the mill-owners—especially by those engaged in the woollen and worsted trades in Yorkshire—and by the linen manufacturers of Scotland; the latter industry having up till this time been also exempt from the application of any restrictive law. Within a few weeks of the introduction of the Bill into the House of Commons, an important meeting of mill-owners was held at Halifax, at which a series of resolutions were adopted which fully embodied the whole case of the manufacturers. It is unnecessary, perhaps, to quote these resolutions in full, but a summary of them will be useful, as showing the arguments used by those who were opposed to Mr. Oastler's impassioned agitation. The employers set forth in their defence that the condition of those employed in worsted factories did not warrant the conclusion that the existing usages of the trade were injurious to the health and comfort of the operatives. Twelve hours labour per day, they maintained, was not attended with injurious consequences, while it was not more than was adequate and necessary to provide for their livelihood. The employers also urged that a law restricting the hours of work and limiting the ages of children employed in worsted factories would produce, among other results, the following:—It would cause a proportionate reduction in wages, and thus cripple the means of those who had large and young families to support; it would raise the price of goods to the consumer, and thus reduce the home consumption; while it would produce the most serious consequences upon the prosperity of the district by fostering manufactures of the same class in foreign countries; it would throw out of employment, and deprive of the means of existence, numbers of children then beneficially employed, and a corresponding proportion of wool sorters, combers, weavers, and others necessary to produce the present supply of goods; the agriculturists also, it was urged, would suffer from a restrictive Factory Bill, because the consumption of wool would be diminished "in no slight degree." In addition to these more general considerations, the woollen and worsted manufacturers of Yorkshire contended that there were special reasons for the exemption of their trades from the application of the proposed Factory

Bill. It was urged that the manufacture of woollen and worsted yarn was a more wholesome and healthy employment than the preparing and spinning of cotton and flax. Neither was it necessary to carry on the processes at such a high temperature. The Bill was also objected to on the ground that it would prove inefficient for the purposes which it professed to accomplish. It was urged that children between the ages of seven and fourteen were really more capable of undergoing long-continued labour than young persons between the ages of fourteen and twenty-one. One-half of the fourteen resolutions adopted at this meeting of mill-owners are directed against the political and social disabilities under which the operative classes at this date laboured, and they help to explain the tendency which the two great political parties in the State indicated, during the subsequent agitation in favour of factory legislation, to take opposite sides upon the question. The year 1831, it must be borne in mind, was one of great political excitement. The whole country was agitated to an intense degree on the subject of parliamentary and administrative reform. The public were also just beginning to appreciate and understand the mischievous influence exercised on our trade and commerce by the protective duties levied upon corn and other important articles of import; and the employers very ingeniously pointed to these as being the real source of the misery, and poverty, and suffering of which the people so loudly complained. Long hours of work were not defended directly, but it was urged that so long as the nation was burdened by oppressive taxation, and so long as trade and commerce were impeded by monopolies and artificial restrictions, it would be impossible for a factory worker to make a wage sufficient to live upon, if their hours of work were limited as was proposed by the Bill then under discussion. In the keen and earnest agitation which took place upon factory legislation during the years subsequent to this date, one can trace these lines of controversy very clearly and distinctly, and they serve unquestionably to explain the apparent party character which it at times assumed.

The opposition to Sir John C. Hobhouse's Factory Bill in 1831 again proved too great and too powerful in Parliament; and although the measure was ultimately passed, yet it was so mutilated that it proved but a small gain upon previous efforts in the same direction. Its application, as before, was limited to cotton factories, and the one step made in advance was the adoption of the clause forbidding night work in the case of all young persons under the age of twenty-one. Practically, this had the effect of abolishing night work in cotton mills altogether, much to the relief and benefit of the operatives. By means of a relay of hands, some mills in Lancashire had been kept running continuously from twelve o'clock on Monday morning till twelve o'clock on Saturday night. Some scandalous cases of oppressive over-work occurred under this system. When an operative in the day or night relay fell sick, his place had to be taken by one from the corresponding relay; and sometimes the same individual was kept at work continuously for twenty-four, thirty-six, and even forty-eight hours at a stretch.

The supporters of the agitation in favour of a further limitation of the hours of work in factories were in nowise discouraged by the rebuff they received in 1831. They felt instinctively that they were gaining ground in the country. Mr. Oastler's energy was untiring, and as the oppressive nature of the work forced upon young children by some of the more unscrupulous employers came to be understood, many mill-owners united with him in the demand for further legislation on the subject. The practical defeat of the effort made to obtain adequate protection to the children employed in factories in the session of 1831, may be regarded indeed as a fresh starting-point in the history of the agitation upon the subject. So strongly were those engaged in it impressed with the growing evils of the factory system, as it then existed, that they were encouraged to demand even a more perfect measure than that proposed by Sir J. C. Hobhouse. The demand for a ten-hours Bill now began for the first time to be heard in the textile manufacturing districts; and in the course of a few years this demand became the watchword of the operatives throughout the length and breadth of the country. Among the members of the House of Commons who had manifested great interest in the Bill of 1831, and who materially assisted Sir John Hobhouse in the debates, was Mr. Michael Thomas Sadler, then member for the borough of Newark. Mr. Sadler evinced a resolution and a determination in pressing this question upon the attention of the Legislature, that he soon came to establish himself in the full confidence of the members of the short-time committees throughout Lancashire and Yorkshire. The difficulties which Sir John Hobhouse had had to encounter in obtaining even his mutilated measure induced him to come to the conclusion that the demand for a law which would reduce the

hours of work to sixty per week was quite impracticable; and while expressing an earnest hope that the supporters of the short-time movement might be successful in their efforts, he declined, in a letter which he addressed to Mr. Oastler in November, 1831, to identify himself with a movement which he characterised as idle and extravagant. Mr. Sadler, however, undeterred by this expression of opinion from a gentleman who certainly had the interests of the suffering children at heart, introduced a ten-hours Bill before the session of 1831 had closed. On the 18th of March of the following year, he moved the second reading of the same measure in a speech of great force and merit, and it was ultimately referred to a Select Committee. During this time, however, the agitation in the country on the subject of parliamentary reform had reached its climax, and all other questions had to give way until it was disposed of. The Reform Bill passed in 1832. Before the Select Committee had concluded their labours, Parliament was dissolved, and as the borough of Newark was disfranchised, and Mr. Sadler failed to obtain a seat in the new House of Commons, another change in the parliamentary leadership of the short-time movement became necessary.

HEMP, FLAX, AND JUTE.—VI.

FLAX SCUTCHING, AND SCUTCHING MACHINES.

By David Bremner, Author of "The Industries of Scotland."

After steeping their flax, the ancient Egyptians beat it with mallets in order to loosen the attachment between the fibre and the core. Until recent years this was the mode of operation which prevailed in all flax-growing countries, and it is still practised in some parts. Louis Crommelin, the leader of the party of French refugees who, on the revocation of the Edict of Nantes, settled at Lisburn, in Ireland, and who did much to establish the linen manufacture in that quarter, adopted, about the year 1705, what he described as "an improved plan of beating flax." According to this plan, the sheaf of flax was placed on the barn floor, opened, and the straw spread to a depth of three inches, care being taken that all the roots were at the same end. The operative then put his foot on the flax, so as to hold it firmly, and seizing a mallet of convenient form, struck or "threshed" the root end of the straw first, and afterwards the other end, until the mass was completely softened, and part of the woody core driven out. The Egyptians followed the beating process by drawing the flax through hooks, which disengaged and extracted the woody stems and coarser fibres. In later times "scutching" supplanted that operation. In Crommelin's day, scutching was performed by the operative taking up a handful of the straw which had been broken with the mallet, holding it in a notch in an upright board, and subjecting it to a succession of blows with a wooden implement resembling a hatchet, or knife with a broad blade. The flax hung perpendicularly against the board, and the blows were given downward, so that the implement may be said to have scraped the fibres. After each blow a slight turn of the hand brought a fresh surface under the implement, and in a little time every particle of the core was cleared off, and the fibre presented a fine and glossy appearance. Though hand scutching has to a large extent been surpassed by machinery, it still prevails in some parts of Ireland, and the manner in which it is conducted differs little from that which Crommelin introduced. Instead of being beaten with a mallet, however, the straw is broken in a "brake," a machine composed of two grooved iron plates, one of which is fixed on a frame or table, and the other on the under side of a wooden beam or arm, hinged at one of its extremities, and so adjusted that when brought into contact the ridges in one plate fall into the grooves of the other. The arm is attached to a spring, which raises it after each blow. Taking up a handful of flax, the operative places it over the lower plate, and by bringing the upper one down smartly, by the pressure of the foot on a treadle, bruises the straw. Another improvement is the attachment to the scutching stock of a leather strap, which acts as a spring, and helps the scutcher to raise the scutching implement after each blow more quickly, and with less exertion than he could otherwise do. An expert hand scutcher can turn out from 8 lb. to 14 lb. of dressed fibre in a day.

One of the earliest machines introduced to supplant hand scutching, consisted of an upright axle

carrying a number of radiating arms, on each of which was fixed a wooden blade, somewhat similar to that used in hand scutching. A circular wood casing covered the machine, and the flax was subjected to the action of the blades by being suspended through apertures in this casing. The machine got through a large amount of work, but a drawback in connection with it was that the fibre was subjected to rather severe treatment, and the amount of tow was greater than desirable. The defects of this machine were largely overcome by placing the axle in a horizontal position, and the blades consequently in a vertical one, so that they struck the flax in exactly the same manner as the hand tool. With the addition of some provision for softening the strokes of the blades, this form of machine came into general use in Ireland, and removed one of the hindrances to extending the cultivation of flax in that division of the kingdom. Both the Government and the Linen Board gave every encouragement for the erection of scutching mills; and the Commissioners of Public Works obtained powers, under the Lands Improvement Acts, to lend money on favourable terms to needy proprietors for this purpose. A mill, containing four stands of apparatus, costs on the average about £104, and with twelve sets £238—that is, for both building and machinery—the cost of the latter item in the two cases being £60 and £150 respectively. Owing to the fact that the mills are run for only half the year—generally from August till February—it is not considered economical to introduce steam power, and consequently the sites for the mills are, as a rule, chosen on the banks of streams capable of supplying the requisite water power. The cost of scutching appears to be greatly grudged by the flax farmers, and on this point Mr. Charley observes:—"The scutching of flax, including attendance of girls or boys, and carriage to and from the mill, costs about 1d. per pound; now, the fibre is afterwards often sold for 6d. per pound; so that the cleaning amounts to one-sixth, or 16⅔ per cent., of the marketable value! Of course, some flax will sell at a much higher rate than 6d. per pound; but, taking even the extra price of 8d. per pound, the cost of scutching will be 12½ per cent. This is, I think, more than the farmer can afford to pay; and it is to be hoped that, ere long, the charge will admit of reduction to ½d. per pound, or at most ¾d. So long as the scutchers expect to earn, during the six months they are employed, sufficient wages to keep them the whole year round, no reduction can be made; but by judicious arrangement, and giving these people regular employment at some other useful and remunerative occupation during the spring and summer, the cost in wages might, I think, be reduced; and the mill owner ought, from patriotic motives, to be satisfied with a moderate profit for his machinery."

A report on the flax scutchers of his district was made in 1875 by the certifying surgeon at Cookstown, under the Factory Acts, which is interesting enough to be quoted entire. The state of matters described in it is not exceptional in Cookstown. Dr. Hamilton says:—

"Cookstown being the centre of a very large flax-growing district, the weekly market held here is the largest in Ireland; above 100 tons of flax being purchased by the Belfast and other merchants weekly during the season from August till spring. The flax straw is taken by the farmers to the various flax scutch mills, of which there are 30 within a radius of five or six miles. These are erected on various small streams in the neighbourhood, and are generally worked by farmers. The mills are of a very primitive kind, being a small house thatched with the straws from the flax after being scutched.

"The scutchers, men and boys, work by piece-work, and get a percentage on the finished flax of so much per stone; consequently, they frequently work late at night to make the more wages. Many of these small mills have only five or six handles, one scutcher working at each handle. The places are badly ventilated, and with low roofs. The dust and spiculæ driven off the flax are quite thick in the atmosphere which the workers have to breathe at all times, and which produces irritation of the air passages, and an almost constant cough and spitting of blood, very frequently ending in phthisis. Ophthalmia also is due to this dust, sometimes ending in opacity of the cornea, which would be more frequent were it not for the intervals of the spring and summer months enabling the workers to recruit their strength in agricultural labour. The permanent injury to their health would, but for this recruitment, be far more serious, since their habits are very careless and intemperate, so that it is a saying here, 'as thirsty as a scutcher.'

"The rollers at which the flax is broken for the scutchers are attended by one person, frequently a woman, who has to breathe the same kind of atmosphere: but, in addition, is liable to very serious injury from being drawn into the rollers by a portion of the flax straw catching round her hand, or by some portion of her dress dragging her hand

HAND SCUTCHERS AT WORK.

into the rollers. The limb is invariably torn and comminuted in a dreadful manner, and sometimes pulled out of the shoulder joint, necessitating amputation of the limb. In several instances life has been lost. Last season, as coroner of the district, I held an inquest on a woman who was instantly killed in a set of these rollers; and, as the surgeon of the workhouse hospital here, I have had, for some years back, numbers brought in for surgical treatment, many of them having to undergo amputation of one or both arms. Little care is taken by the owners of the mills to protect these workers, for, if a strap was passed over their shoulders and fastened by a chain or hook behind the roller, it would prevent them suddenly being dragged forward, and save many a poor worker from injury and mutilation.

"Whisky drinking being carried on at these places to a great extent makes them the more liable to injury. The farmers often bring the drink in their pockets to encourage them in expediting their work, and so be ready for the first market.

"The strickers are generally women or young girls, who make up the rolled flax into handfuls for the scutcher. They are more in the open air, and not so subject to the suffocating dust as those inside the mill, but suffer in their morality sadly from the late hours and other associations common to such places.

"In the mountainous districts they have of late years become addicted to æther drinking as a rapid and cheap stimulant. This they can procure in any quantities at the small country grocers'. I attribute the development of this taste to the difficulty of procuring whisky in some country districts remote from a town, and the rapid action of the æther as a stimulant and its much greater cheapness than whisky or brandy here in the North of Ireland. (I made inquiry whether the æther was nitric or sulphuric, but I was assured it was the latter.) Mechanics and workmen of all kinds seldom drink beer as they do in England.

"Women who are much engaged in mills and factories make very bad housewives, and their children are sadly neglected, the very young suffering most. I have known a female worker leave off work on a Saturday afternoon, give birth to a

child, and return to her work at six o'clock on Monday morning: certainly a bad way of restoring health, as she is also often but poorly nourished, not to speak of the great neglect of her offspring. I consider the children in this district who present themselves for certificates more delicate and of smaller growth than I knew them formerly, and I have experience of more than thirty years as certifying surgeon. This I attribute also partly to the constant use of badly prepared tea and coarse and underdone soda bread, flesh meat or a good soup being seldom used; and consequently scrofula and skin diseases of various forms are often present. The use of the bath is almost unknown, and dirt and squalor are common in their houses; and in my visits among them I am often shocked at the state of their bed-clothes, and at the want of suitable healthy ventilation of their houses.

"Sunday is too often spent by the parents and grown up children in drinking bad whisky. Even the proprietors of mills frequently deplore their inability to check the habit, and say that the high wages and shorter hours of work have only made them worse, by giving the workers greater facilities for debauchery.

"The above report is but a meagre outline of the habits and mode of life of those engaged in the preparation of flax for the market; and any improvement that may take place in their work rooms will be by steam power and large buildings being erected instead of the wretched hovels now in use, and the introduction of improved machinery superseding the present primitive structures in most country districts. Safety to life and limb cannot otherwise be carried out by any inspection in remote districts very difficult of access."

Once begun, the work of improving the appliances for scutching went on, and now there are a variety of machines in the market. Mr. M'Adam, of Belfast, introduced fluted rollers for breaking the flax straw before scutching, and also the simplest form of mill for cleaning the flax — that already referred to, in which the operation is performed by a series of blades attached to radiating arms fixed on a horizontal axle. Mr. Robert Plummer, of Newcastle-on-Tyne, improved upon Mr. M'Adam's breaking machine by arranging the

Interior of a Scutching Mill.

rollers in a more compact way, and so that the one does not actually bear on the other, thus avoiding injury to the fibre. He also invented the disc scutching machine, in which whalebone brushes take the place of the wooden blades of Mr. M'Adam's machine. For this invention several advantages are claimed; but as yet they have not been fully recognised. In substituting a pliable body like whalebone for the hard, unyielding wood of the scutching blade, Mr. Plummer calculated that he would be able to rub off the woody part of the straw with the least possible injury to the fibre. By placing two discs together face to face, both sides of each bunch of flax can be operated upon at once; and if three discs be used, the workman could simultaneously deal with a bundle of flax in each hand, thereby doubling his own working capacity. The brushes are made separate from the discs, and may be adjusted on them at any convenient angle, or shifted about so as to be equally worn. As the brushes revolve, they are kept clean by passing over a steel comb. Another device of the same inventor is the double-cylinder flax-brushing machine, in which the flax is operated upon by being suspended between two brush-covered rollers revolving in opposite directions. Mr. M'Bride, of Armagh, has invented a scutching machine that is most favourably spoken of, and is certainly remarkable for the ingenuity displayed in its construction. It consists of two chambers, in each of which is inclosed revolving beating apparatus of peculiar construction. Through these chambers a pair of endless ropes pass, and carry in their grasp a continuous supply of flax straw. The flax is fed in between the pulleys which carry the ropes, and is grasped between the folds, about two-thirds of the length of the straw depending below the ropes. In passing through the first chamber, the flax is beaten rapidly and thoroughly, and has fully half its length cleaned. On leaving the beater, the flax passes to another pair of ropes, which nip it in the lower part, and the first ropes relaxing their hold, the undressed part of the straw falls down and becomes pendent. In this way the flax is carried into the second chamber, in which the scutching process is completed. After passing the beaters, the flax is carried forward and delivered at a convenient point. With four attendants, the machine will get through a ton of flax in a day. A machine bearing some resemblance to this one, but said to be superior in certain respects, is in use in Belgium. Messrs. Rowan, of Belfast, invented a scutching machine some years ago which was received with considerable favour. It is described as follows in "Ure's Dictionary":—

"The flax straw is not previously bruised, but is at once fastened in iron clasps which are placed in a slide, the action of the machine carrying them on along one side, while two parallel bars of iron, toothed, comb the straw and separate the woody part from the fibre. The first portion of these bars has coarse teeth, and the teeth become closer by degrees up to the end of the slide. There a workman or boy takes out the clasps, unscrews the nuts fastening them, and reverses the position of the straw, so that the portion not previously subjected to the action of the machine is now presented to it, while that already cleaned out is untouched. This machine is double—*i.e.*, has two sides of combs, each capable of containing twelve of the clasps, and each cleaning out one end of the flax straw. Hence, after the workman or boy has unclasped the half-cleaned straw, turned it upside down, and presented the uncleaned end to the other side of the machine, the same action of combing, already described, clears out that end thoroughly; and by the time the progressive movement of the mechanism brings the slide to the extreme end, the flax fibre appears free from woody refuse, and in a fit state for market. It is then unclasped and made up in bundles."

In scutching, the chief object is to extract from the flax straw the greatest possible quantity of fine fibre. But no matter how carefully the operation may be conducted, a considerable proportion of fibre is driven off along with the woody refuse. This is called "scutching tow" or "codilla." It is not absolute waste, because it can be cleaned to some extent, and spun into yarns suitable for making sacking and other coarse fabrics; but its value is only about one-tenth that of the finer product. Even when every bit of fibre is separated from it, the woody fragments of the stems form a bulky part of the crop, and it has occurred to many minds that it might be made to yield some return to the farmer. It is sometimes used as manure, and also as fuel, and serious proposals have been made to raise it to the position of food for cattle. In the latter capacity it would, however, be little more nourishing than the pulverised stone with which the people in the famished district of Northern China tried to stay the pangs of hunger in the famine of 1877, for it has been found on analysis to contain only 3·23 per cent. of nitrogenised flesh-forming matter, 2·91 of oil and fatty matters, and 14·66 of gum and soluble matters.

IRON AND STEEL.—VII.

THE FORGE.

By William Dundas Scott-Moncrieff, C.E.

AMONG all the processes which we have hitherto described as necessary for the production of iron, there is none that is so picturesque in its associations as the forge. Even in the earliest days of the iron manufacture in Great Britain, when the Romans with their air-bloomeries were extracting the metal from the ores of the Dean Forest, there could never have been anything in the process of smelting that was likely to attract the eye of the poet or the artist; but from time immemorial the smithy has afforded materials for both. It is only within a comparatively recent period, commencing with the inventions of Henry Cort and the larger appliances of the rolling mill, that any change has taken place in the primitive apparatus of hammer and anvil; and wherever the manufacture of iron is carried on under the old-fashioned system that sufficed for the wants of our ancestors, there still remains the old picturesqueness which must have been at one time its distinguishing characteristic. Dr. Percy, in quoting from Dr. Hooker's Himalayan journals, seems to be struck with the idea of a botanist, whose love for plants and trees was likely to lead him to speak adversely of any process that consumed them so ruthlessly, referring to the forges of the Khasia Mountains in the language of romantic appreciation. Even among the splendid scenery of the Himalayas, he sees nothing incongruous in the presence of iron factories; and so we may conclude that in our own country there was nothing offensive in the olden days, when they were conducted in an equally primitive manner. In one of his descriptions, Dr. (afterwards Sir) J. D. Hooker says:—"Few houses were visible, but the curling smoke from the valleys betrayed their lurking-places, whilst the tinkling sound of the hammers from the distant forges on all sides was singularly musical and pleasing; they fell on the ear like 'bells upon the wind,' each ring being exquisitely melodious, and chiming harmoniously with the others. The solitude and beauty of the scenery, and the emotions excited by the music of chimes, tended to tranquillise our minds, wearied by the fatigues of travel and the excitement of pursuits that required unremitting attention; and we rested for some time, our imaginations wandering to far-distant scenes, brought vividly to our minds by these familiar sounds." How different, alas! from our own Black Country, where these primitive processes have been developed by the ingenuity of the last few generations! In the small forges to which Dr. Hooker refers, the appliances are of the rudest description; so simple are they, indeed, that Dr. Percy inclines to the belief that they must have been used a long time previous to the introduction of bronze, which requires much greater skill for its production. This opinion is directly opposed to that of archæologists, who seem to be quite agreed that the age of bronze preceded "the age of iron"; though Dr. Percy combats this with the assertion that iron rusts away so readily that it may have all disappeared, leaving nothing but bronze as a record of the earliest metal in use. Speaking of the easy way in which iron can be produced in these small furnaces, he says:—"If a lump of red or brown hæmatite be heated for a few hours in a charcoal fire, well surrounded or imbedded in the fuel, it will be more or less completely reduced, so as to admit of its being easily forged at a red heat into a bar of iron."

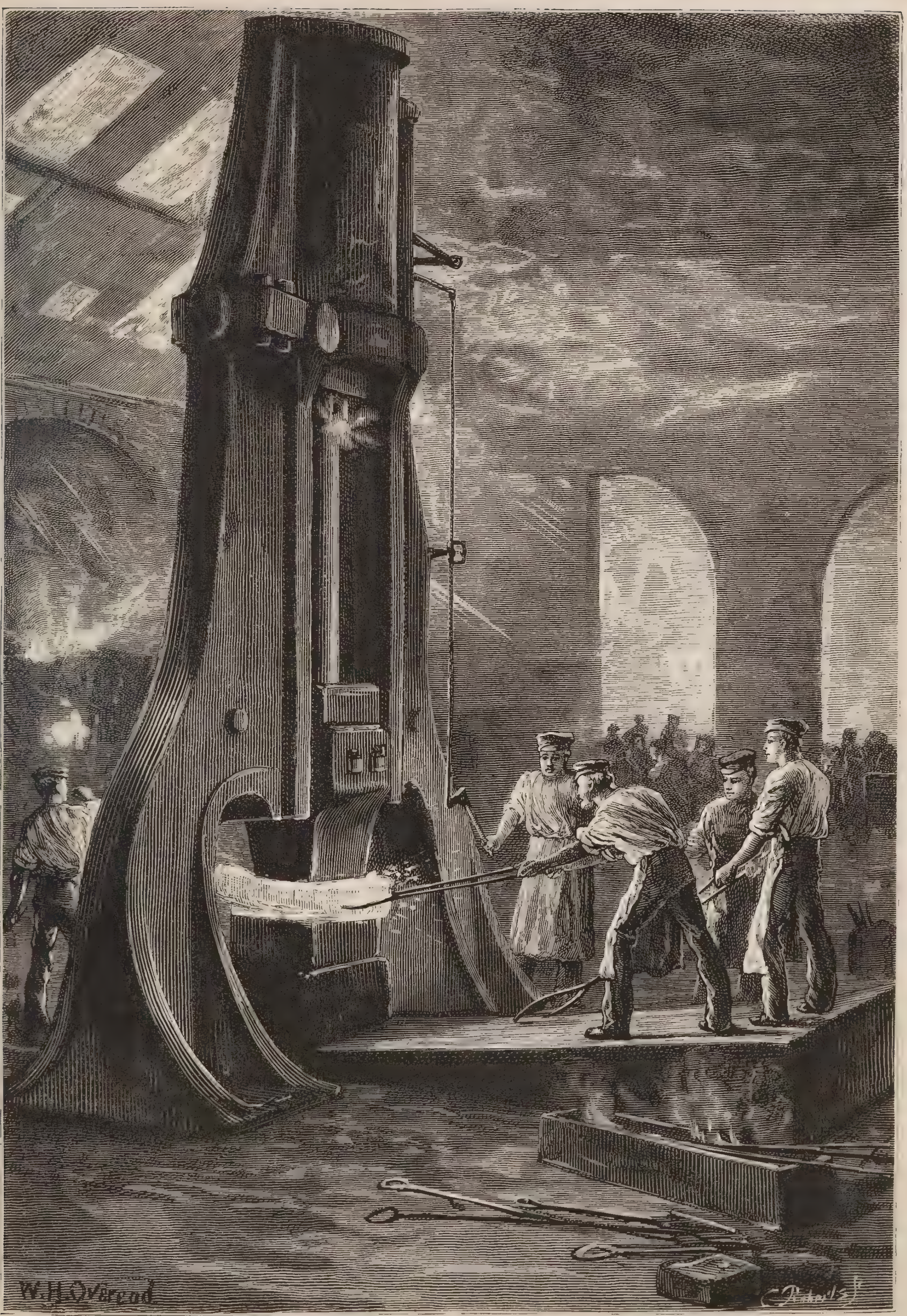
Although reducing iron from the crude state is really more closely connected with smelting than forging, it is still associated in name at least with the latter process, and has been carried on from time immemorial in various parts of the world, so widely separated that it would be impossible to trace their common origin, if it ever existed.

It would occupy too much space to give even an outline of the different localities where forges are carried on, or to go into detail as to the particular appliances employed. In Central Africa, separated by hundreds of leagues from the nearest civilisation, they are conducted to an extent that is quite surprising; and the description of a well-known traveller seemed almost beyond belief to the present writer, when he heard in conversation the narrative of that distinguished eye-witness.

All these forges depend upon the same conditions of fuel and an artificial blast of air, the only difference being the mode of applying them, which has already been referred to in the first chapter of this series. In Europe there is a process which still survives, and which is known as the Catalan forge, from the province of Catalonia, in Spain, where it was probably first introduced—at least into that part of the Continent. The historical and technical

interest which attaches to this process is so great that we will give a short description of it. There are records of the manufacture of iron having been carried on among the French Pyrenees so early as the thirteenth century; but it is probable that it existed long previously, and there is little doubt that from this source came many of the weapons and much of the armour of mediæval warfare.

Till towards the beginning of the eighteenth century, bellows were the only means employed for producing the blast; but about that period an appliance was employed which is so curious that it is deserving of special mention. This is known as the Trompe, and was the only apparatus employed up to very recent times among the Catalan forges of the Department of Ariége. It is believed to have been introduced from Italy, and to have been invented there in 1640. Although the scientific principles upon which this curious apparatus depends are essentially different from the well-known Injector of Giffard, by means of which cold water is forced directly into a boiler by a jet of steam, there is a strange similarity between them. In both cases the adjustment of a nozzle is an essential element of efficiency; but in the trompe it is arranged so that a jet of water entangles a quantity of air from the atmosphere, carrying it along in its descent to a large tank, where both are separated at a pressure sufficient to maintain a considerable blast. At one time the theory of the trompe created a great amount of scientific inquiry; and we are not aware of its having been settled upon any authoritative grounds. In 1800, Venturi accounted for the blast "by the motion which he supposed the falling stream of water communicated to the surrounding air in contact with it." His reasons for coming to this conclusion, however, could not have been very convincing, because so late as 1848 Magnus, Professor of Physics in the University of Berlin, affirmed "that the true physical cause of the rushing down of the air was still quite unknown." Without offering any alternative theory to that of Venturi, it will be sufficient to give a short description of the apparatus which at one time gave rise to so much scientific discussion. With the exception of a few pipes and connections, the trompe is constructed entirely of wood, and consists of a strong tank (*paicherou*) holding several tons of water, which is placed at an elevation of between 20 feet and 30 feet above another tank, with which it communicates by one or more wooden pipes called trees (*arbres*). It is the peculiar manner in which the water is allowed to pass from the upper to the lower cistern which constitutes the efficiency of the apparatus. A wooden nozzle, with an adjustable plug under the control of the forgeman, brings the water into the upper extremity of the pipes or trees in the form of a jet; and just at the point where this jet is formed there are openings through the sides of the pipe, inclined downwards at an angle of about 40°, so that the water at this particular part of its descent is in direct contact with the outside air, which descends in considerable quantities to the lower tank, or wind-chest, where the air is released, and escapes in the form of a blast. The pressure varies from 3 inches to nearly 4 inches of mercury, or about $1\frac{1}{2}$ lb. to 2 lb. pressure on the square inch. Where there is an ample supply of water, the trompe is a very useful and easily maintained form of blowing engine, its chief defect being the moist state of the air on reaching the furnace, which consists of a simple hearth placed against a wall on the level of the floor. Dr. Percy, in his "Metallurgy of Iron and Steel," gives a long and interesting account of the Catalan forge; and we may here briefly give some idea of how one of these small establishments is carried on. The *personnel* consists of ten persons—eight forgemen *(forgeurs)*, and two business men. The former number is made up of a foreman *(foyer)*, who has a general superintendence of the machinery; a hammerman (*maillé*), who looks after the treatment of the iron under the hammer, and has charge of all the tools connected with it; two smelters (*escolas*), who look after the charging and working of the furnace; and an assistant to each, which makes up the eight. Even in these primitive establishments the *truck* system exists; and one of its most objectionable points is said to be the habit of allowing the manager to be the purveyor of bread and wine to the forgemen. As a rule, the ironmasters who own these forges hand them over to the control of an overseer, who is generally not only ill-informed and ignorant, but entirely at the mercy of the prejudices of his workmen. There are two kinds of iron which come from the Catalan forges—one "fer doux," soft iron; and the other "fer fort," or steely iron. The softer descriptions seem to be of fair quality in the matter of fibrousness and malleability, but as a rule they are not sufficiently freed from impurities to be reliable. Dr. Percy concludes his description of the Catalan process with one or two remarks, which must serve as an apology for the time we have occupied in describing it:—"It will, perhaps, be considered by some persons that I have described the Catalan



Nasmyth's Steam Hammer at Work.

process at unnecessary length, because it is now defunct, or nearly so, in Europe, and is not likely to be revived. But surely the process by which all iron was formerly produced merits more than a passing notice, on the ground of historic interest alone. There are, however, other reasons which have induced me to present a detailed account of this process. Such an account teaches much which will be of use in our future inquiries, and may be useful to emigrants in some distant and comparatively inaccessible region, where the Catalan process might be carried on with advantage, and compete successfully even with British iron." We have taken the Catalan process as typical of many others, which it would be beyond our purpose to describe. There is the Corsican process, which has all the appearance of a common smith's forge; the Osmund furnace, of Sweden, which was more of a blast furnace; and so on.

Coming now to the development of the forge in this country, it may be said to have followed those appliances which became necessary for the production of malleable iron on a large scale. No sooner had Henry Cort introduced the system of rolling mills, than larger hammers became necessary for "shingling" the puddled balls; so that, even before the introduction of the steam hammer, there was machinery available for forging upon a considerable scale. In speaking of the steam hammer in the last chapter, we omitted to mention that the first patent on the subject was taken out in 1784, by James Watt, whose far-seeing genius anticipated so many of the inventions of the present century. It does not appear that he conceived the idea of a hammer acting directly, by a blow of the piston, as in Nasmyth's, or of the cylinder as in Candie's; but, as the diameter of the piston he proposed was 15 inches, he must have contemplated the construction of a machine of considerable dimensions, though it is not within our knowledge that he ever carried it out. Practically, the *plant* of a forge is very similar to that of a rolling mill, in so far as the most important appliances of both consist of reverberatory furnaces and steam hammers, the former being used in rolling mills for puddling the pig iron and rendering it malleable; and in forges, in a somewhat modified form, for heating the masses of wrought iron, in order to render them sufficiently soft for treatment. Generally speaking, in both forges and rolling mills, the waste heat from the furnaces is made available for raising the steam necessary for working the steam hammers, by being passed through boilers arranged for that purpose. Although the strides that have been made during the last fifty years in every branch of the iron industry have been so great that one might suppose each of them to have advanced independently of the other, upon looking back it becomes apparent that every branch was really dependent upon the other, and that any difficulties which remained unsurmounted in one, would have retarded the progress of all the rest. For instance, it is hardly conceivable that such a gigantic construction as an ocean-going steamer, or an armour-plated war vessel, could have had any existence, if it had not been for the previous introduction of the steam hammer; and this will be readily understood when it is explained that many of their essential parts are altogether the production of the forge. The screw and paddle shafts of marine engines, and the stem and stern pieces of ships, bulk more largely in the productions of our large forges than all the rest of their output added together. No better explanation of the way in which these huge masses of iron are produced can be given, than by simply saying that they are like the production of a single blacksmith upon a gigantic scale. First of all, scraps of iron, many of them no longer than a penny piece, are built together on little frames of wood, as in shingling, and raised to a welding heat in the furnace. In this state they are reduced to a solid mass by the blows of the steam hammer, and being again heated, are welded together, till a sufficient mass has been obtained—that is, shaped as nearly as possible to what is required, by repeated blows. The greatest skill and attention are necessary during the whole of this tedious process, as every time the iron is heated, it is liable to injury from a misapplication of temperature. When the forging has been brought as nearly as possible to the proper shape, if it is to be altogether round, as in the case of a propeller shaft, it is taken to a gigantic turning-lathe, where it is finished; or if there are flat surfaces, as in crank shafts, it is first placed in a planing machine, and then taken to a lathe to be finished. The gigantic scale on which everything has to be carried out, is the only peculiarity of the work of finishing the forgings, as the process in no way differs from the manner in which malleable iron is converted into machinery upon a smaller scale.

There is perhaps no one who has done more to improve upon the appliances of the modern forge than Mr. Fraser, of the gun factory at Woolwich, to whose genius the country is indebted for the many inventions that were necessary for the production

of the famous guns known as "Woolwich Infants." The mass of iron required for making a large piece of ordnance is so enormous, that makers despaired of being able to produce it in one piece, and so introduced the system of building them together in thin coils. It is upon this plan that the well-known guns of Sir William Armstrong are constructed; and it is to Mr. Fraser that the country is indebted for a cheaper and more durable weapon. It can readily be understood, that where a gun has to be constructed of layers of iron, every one of which has to be fitted to the other with an exactness that exceeds in its nicety every other production of the kind, great expense must be incurred; and that even when the utmost perfection in its construction has been reached, it can never have the same solidity as a homogeneous mass of iron without flaws. The practical difficulties in carrying out Mr. Fraser's plan of solid forgings were immense, but the appliances he makes use of are so complete, that the largest guns are turned out with greater ease than many of the forgings of other establishments, which are only half the weight. The first great practical improvement was forging the heavier masses in the form of gigantic bars, something in the manner of the barrels of small arms. By first heating a square bar in a furnace, and then fixing one end of it to a huge roller, which twists it round like a piece of wire, when it is converted into a coil and then slipped off the end of the roller. It is next subjected to a welding heat, and in this condition is removed from the furnace by a pair of leviathan tongs that are suspended from a steam crane, by means of which it is placed under the steam hammer, where by a few blows it is turned into a solid cylinder of malleable iron. In this way, instead of thin laminations, the structure consists of only two or three thicknesses, one of which forms the barrel, and the other, the outer layers that are such a prominent feature in the shape of a "Woolwich Infant."

The perfect manner in which means are adapted to the end in working with these great masses of glowing iron, enables them to be produced without the expense of any extraordinary exertion on the part of the workmen; and we know of nothing that better illustrates the capabilities of modern appliances than the inventions introduced by Mr. Fraser for the production of these huge pieces of artillery. Much time might be occupied in a description of other specialties of the forge, such as chains and anchors, but as they all depend upon the same conditions, we have chosen the larger productions as best suited to the purpose of illustration.

In our next chapter in this series we propose to give some account of the Bessemer process for producing steel.

WOOL AND WORSTED.—VI.

MOHAIR.

By William Gibson.

AMONG the most interesting incidents the traveller in the South of France meets with is the mode in which flocks of sheep are moved from the rich plains to the table-lands of the Pyrenees or the Alps, where the air is bracing, and the grass tender and succulent. Instead of the dog, faithful and intelligent, the shepherd employs a small herd of goats—hardy, adventurous, obedient to the word of command—as fuglemen to the sheep. These goats are trained to stop or go on when ordered; and when they have, by unerring instinct, guided their charge to some grassy plot, or snug shelter from the bitter wind, they roam away to the giddier heights to feed on scantier herbage, but are ready at the call of their master to return, and, like the pioneers at the head of an army, resume their march in front of the herd. So, in the old days of the patriarchs, were the goats and the sheep mixed in one flock; and so do we find the Bedouin now, in the *wâdys* of Sinai and the hill-country beyond Jordan, employing the same hardy animals as pasture hunters for their less intelligent companions. But this is not the only use to which they are put by the sheep farmer.

Goats' hair is among the first, if not absolutely the first animal substance, used in the manufacture of human clothing. Far back in dim antiquity, our rude forefathers in the valley of the Euphrates, the Jews and Egyptians, the wild hunters of the mountain fastnesses of Asia Minor, the aboriginal inhabitants of the New World, the Celts in Ireland

and Northern Europe, had discovered the method of making artificial coverings from the fleeces of the goat. It was of this material the gorgeous curtains for the tabernacle in the plains of Sinai were woven; it was with goats' hair that Saul of Tarsus made those tents by the sale of which he mainly supported himself during his arduous missionary journeys at the dawn of Christianity; and it is from the down that grows beneath the rougher outward covering of the she-goat that those splendid specimens of colour, texture, and delicacy of workmanship—the cashmere shawls—are produced. Mohair was in very general use in Europe during the Middle Ages, and a considerable number of men were employed in its manufacture. Among the most expensive and prominent exports from the Levant during the Commonwealth in this country was Angora wool, spun and ready for the loom. There are two main classes of goods into which the hair of the goat is woven—viz., cashmere, and mohair—the former being an admixture of goats' hair with silk, and the latter with sheeps' wool.

Although goats'-hair cloth has never ceased to be manufactured in Europe, or worn by various classes of society, it gradually declined in public estimation as fabrics of sheeps' wool became popular. An apparently insignificant circumstance gave this species of texture a new lease of popularity in Western Europe about the year 1820. Cashmere shawls were at that time in great request in France; and a French weaver of very great eminence and enterprise, named Ternaux, of St. Ouen, fired with the desire of introducing the manufacture of cashmere shawls into his native country, and hoping to make a fortune by the venture, undertook a journey to the fair annually held at Novgorod, in the expectation that he would there meet with some of the spun fleece he was in search of. Nor was he disappointed. And one of the immediate results was that M. Ternaux engaged an agent to proceed to Central Asia, and bring over to Western Europe a flock of the celebrated sheep. These were publicly exhibited in France in the year 1823, and immediately incited breeders to attempt the naturalisation of the Angora in that country. The matter was eagerly taken up by Messrs. Faciot, of Montmartre, and Bietry, of Villepreaux, and resulted favourably. In 1827, the chief agricultural society offered a prize for increase in the flocks which had been located in the country. There was a very fair gathering of lambs from the various broods, and the prize—a silver medal—was awarded to M. Polonneaux. It was found that the best crosses were obtained with the Angoras and Thibetans, but good results were the outcome of a mixture of Angora and the best Indian breeds. Meanwhile, M. Ternaux had constructed a plant of special machinery for the manufacture of shawls; and his goods, though inferior in workmanship, fineness of texture, and wealth of colour to the true cashmere fabrics, were eagerly sought for, and bought more rapidly than they could be produced. The breeding of the sheep had not, however, reached that point of excellence by which wool equal to that sold in the Russian market could be procured, and consequently M. Ternaux continued to import the raw material thence. Several other manufacturers now entered the field as competitors with the original producer of this class of goods; and, though the fabrics they turned out were on the whole creditable, M. Ternaux still held the foremost place in public estimation. Naturally enough, M. Ternaux improved by the increase of experience, and the proverbial good taste of French designers and the aptitude of French workmen for the production of artistic materials powerfully aided him in his enterprise. The other manufacturers, finding themselves outstripped in the race for favour in the shawl trade, turned their attention to other fields; and thus was founded the great mohair and cashmere manufactures of that country. In order to show the zeal with which that class of labour was entered upon, and the extraordinary popularity of the fabrics offered, it may be stated that in 1835, or about ten years after M. Ternaux's first shawls were put into the market, the annual value of manufactured mohair had risen to no less a sum than 30,000,000 of francs, or £1,200,000 sterling. Spinning and weaving factories had sprung up in the departments of the Rhône, De l'Aude, and elsewhere. St. Ouen, Nîmes, Lyons, Perpignan, and Paris became great centres of the trade. In Paris alone there were eleven large shawl manufacturers, and three who devoted themselves exclusively to the production of the Ispahan pattern.

One of the most interesting facts in connection with the history of the manufacture is the means by which the taste for this special class of goods was promoted. From the time of the Crusades down to the beginning of the present century, the East and West practically held but little intercourse; and while the manufactured goods of the Occident found their way into Asia, chiefly through the enterprise of the East India Company, few of the native productions of the Orient came amongst us. Napoleon's campaign in Egypt,

disastrous as it was in a political sense, was rich in its contributions to the commerce and manufactures of Western Europe; and it is to the officers of the army of the *Petit Caporal*, who wished to please their wives, sisters, and sweethearts with the beautiful and gaudy products of Eastern looms, that we owe the introduction of cashmere shawls, and, in a secondary sense, the present position of the manufacture of goats' hair in this region of the world. These gentlemen invested largely in such goods, and quite a furore was created in Paris, upon the return of the army from the East, by those ladies whose friends and relatives gave them the means of arraying themselves in the new and gorgeous *articles de luxe*.

England all this time had done nothing to emulate, and very little to promote, the new manufacture of France. We had, it is true, a small and growing trade in mohair camlets; but, for the most part, our weavers imported hanks of the spun yarn from Smyrna. Our native spinners declined altogether to have anything to do with the raw material, for the reason, as they alleged, that the wool was too short in the "shaft" to yield results worth striving for. How they could have arrived at such a conclusion with the Smyrna yarns before them, and with the knowledge of what had been done in France, is a mystery; but the truth is, that to promote any new industry it requires one man of genius and enterprise, who "laughs at impossibilities, and says it shall be done." That prime factor introduced, the rest is merely a matter of time.

There was, however, one man in this country who, though not a manufacturer himself, had a fine discernment of the capabilities of English mechanical skill; and, if he had not directly made his mark in the fabrication of home products, was a great power in a direction very closely allied to that department of national industry. He had long been known to colonial breeders of sheep as one of the shrewdest and ablest advocates of a scientific system of crossing varieties, for the purpose of reaching the maximum of weight, fineness, and length of wool; and had done much to awaken breeders abroad to their true interests, and manufacturers at home to the fertile sources of increasing our area of supply amongst our brethren, who had ventured to the isles of the sea, and carried British pluck and energy to our young colonies. He was also known on the wool exchange as one of the princes of wool merchants—a man whose judgment and integrity could be relied upon, and one whose special knowledge had been of shining utility to the English woollen manufacturers. As he never permitted anything to slip by uninvestigated which might benefit himself as a broker, his friends as woollen manufacturers, or his country in textile commerce, nothing that was going on in any part of the world, in connection with the great industry with which he stood associated, was allowed to pass. It is due to him absolutely that some of the earliest efforts were made in experimenting in Bradford upon alpaca; and it was through his hands, we believe, that the fleeces of the lamas in Windsor Park were sent to Yorkshire, and made into the first alpaca dresses worn by her Majesty. Thomas Southey, wool broker, of London, is a name that must live as long as the alpaca trade endures; and, though his biography may not essentially differ from that of any other successful and intelligent merchant in the great metropolis, yet his name and contributions to the wealth of the country ought to be held in lasting esteem. Thomas Southey knew what was going on in France; wondered that no English manufacturer had ever turned his attention to the new industry; and formed the fixed determination of seeing the hair of the goat yet spun in England, and fabrics woven from the yarn better in quality and larger in amount than the gross product of the neighbouring nation. But the steps he undertook to attain the end he aimed at will best be told in words which he wrote in 1848 in his work on "Colonial Wools." He says:—"In my former treatise, I ventured to express the hope that the wool of goats would be spun and largely woven in this country. It has become a source of pleasure to me to know that this desirable object has at length been attained; and I rejoice to add that British Angora's wool yarn is now more esteemed than that of Asia Minor. The means by which this improvement was attained I will briefly state. Impressed with the idea that Angora wool could be spun in England, I took a small sample of it, together with some yarn of the same material, with me when about to visit a friend at Thetford, to whom I communicated my wishes, and he gave me an introduction to his agent at Norwich. After some preliminary conversation, the latter replied that he thought the undertaking could be accomplished, and would see that it was done. In the course of a fortnight afterwards, a person came to town with a letter from my friend's agent, and purchased two bales of Angora, which I learned were forwarded to Bradford. I proceeded there on my return from Scotland, with a view to ascertain what parties were consuming the article, and I was not long in discovering the

residence of the fortunate person who accomplished this laudable object of the manufacturer's ambition."

Such is the simple story of the introduction of Angora wool as one of the staples of home consumption; and it is to the enterprise of the Bradford manufacturers that England is indebted so deeply for its splendid woollen fabrics. Spinners soon learned that the shortness of the "shaft" was no insuperable difficulty to English skill; and, as is the case in this country in regard to most things, however reluctant we may be to take a thing up, once having determined to experiment upon it, we try our very best to outstrip all competitors. Hitherto, as has already been said, the Angora yarn was imported from Asia Minor; but as soon as English spinners really got to work upon the material, the exportations from Smyrna gradually declined, and at the present time the trade in Levant yarn has practically ceased. This will be seen at once from a comparison of the number of bales of yarn exported from Asia Minor in the three years after the spinning of the wool was first taken in hand in this country. The first yarn spun in England was in 1836, and in that year 538 bales were shipped at Smyrna. The following year only 8 bales left that port, and, though endeavours were made to force the trade in 1838, not more than 28 bales could be got rid of; while in 1839 there is no record of a single bale having been shipped. France, however, now began to get fleeces through the merchants at Constantinople, as well as from the caravans that came annually to Novgorod. In 1836 that country imported from the metropolis of Turkey 3,841 bales; in 1837 there was a fall to 2,261; but in 1838, when the wool was beginning to be demanded in the English market, 5,528 bales came from the Golden Horn; and in 1839 there was a further increase to 6,000 bales. Of these latter, England took from 1,000 to 1,500 bales, so that in three years the demand in this country had enormously increased. These statistics, however, must not be taken as exhaustive or absolutely exact, because the means of registering exports either at Smyrna or Constantinople were defective. It was nobody's business to see that it was correctly done, and the figures quoted were brought together by our consular agent in Asia Minor, Dr. Bowring, who collected a number of interesting statistics regarding Syria from the best sources open to him.

Mohair, the term now used for mixtures of goats' and sheeps' wool, comes to us from the same source as the French equivalent *moire*, which seems to have been derived from the Indian word *moiacar*, the name by which goats' wool was known in that country (see p. 142). The species of goat known as the Angora exists in greatest perfection in Asia Minor and Central Asia. Its fleece is white, and the coat is of the same length and quality throughout. In the districts where these goats are most perfect, the cats and greyhounds have similar long, white, silky, and slightly curled coats, and they thrive best in mountain plateaux from 1,500 to 2,500 feet above the level of the sea. The best fleeces are exported by a tribe called the Yoorooks, who take great care to keep them clean. The fleeces—*tiftik*, as they are called—are clipped in April and May, and yield each from $1\frac{1}{2}$ lb. to $2\frac{3}{4}$ lb. of wool. The wool of the female is the finer and heavier. About a two-hundredth part of the total female yield is retained for the finest home manufactures. The outer hair of the he-goats and barren females is separated from the skins, by lime, after the animals are killed, and sent to Constantinople, where it is used in making slipper-uppers. Some skins are cured with the hair on, and these fetch 20s. each in Angora, and about 50 per cent. more in Constantinople. The women of the country were formerly employed in combing the wool, and at that time there were six qualities of yarn spun. The first, second, and third were chiefly used in France, Holland, and Germany, and the three highest in England. One great difficulty that was found by French and English manufacturers of cashmere and mohair was to get the wool to take a dye effectively. In Angora, the yarn went through a process of being moistened in the liquor of what is called *chirish*—a plant of the asphodel species, which grows plentifully in Asia Minor—and it is believed this makes the yarn dyeable.

Eastern spinners and weavers used goats' hair for many purposes to which those in England and France never applied it. For instance, some years ago among the specimens of Armenian workmanship brought to this country were parcels of scarves, gloves, socks, and other garments. Samples of these were shown to some of our Leicester manufacturers, and so skilful and perfect was the workmanship that they could not tell where the work began and where it finished. In this country and France, mohair is chiefly used for ladies' dresses and cloaks. The materials are sometimes the natural colour of the yarn; sometimes it is dyed a uniform colour; and, though not perhaps so popular now as heretofore, dress pieces in stripes and checks are in use. Angora

wool and silk stuffs are also in considerable repute. The chief manufacture of all classes of mohair is carried on in Norwich and Bradford, in the South of Scotland, and in France; but almost all manufacturing countries in the world use more or less of it, and the yarn so used is now almost entirely imported from the Norwich and Bradford districts, where spinning is carried on to a very large extent. Both the spinning and weaving of mohair materials have sadly declined in Armenia. While 1,200 looms were fully employed in Angora alone, there are not now 50; and the 20,000 pieces of stuff that used to be annually turned out in this district have now fallen to less than 1,500. When the wool first came into England, it was worth about 10d. per lb. Between 1826 and 1840 it gradually rose in value to about 1s. 8d. per lb., and now it is worth from 2s. to 2s. 3d. per lb. The two bales originally sold from the warehouse of Thomas Southey did not fetch more than 9d. per lb.

The processes of manufacture are very similar to those through which the alpaca goes in its transformation from raw wool to a woven fabric, and the reader may be referred to the articles on that subject in reference to the stages of its metamorphosis. It will, therefore, be seen that the progress materially depended upon the success with which the spinning, weaving, and dyeing of alpaca were accomplished; and, looked at from that standpoint, to the labours of Mr. Foster, of Queensbury, Sir Titus Salt, and other Bradford manufacturers, is due the prominent position which this particular branch of textile fabrication holds among the woollen industries of England.

Angora Goats.

MODEL ESTABLISHMENTS.—IV.

THE ALSTON WOOL-COMBING WORKS OF MESSRS. ISAAC HOLDEN AND SONS, AT BRADFORD.

By James Burnley, Author of "Workshops of the West Riding."

THE skill of the inventor has in no branch of manufacture produced more remarkable results than in wool combing. For at least half a century after the introduction of steam as a motive power, inventors were at work in England, France, and America, endeavouring to bring to perfection a machine to supersede combing by hand, and, after much patient toil and disheartening failure, they at last succeeded, and a machine was produced which was capable of manipulating wool with much greater delicacy and dexterity than the hand comber had ever been able to do. The wool-combing machine effected a complete revolution—both social and industrial. Up to that time the hand wool combers had formed a considerable proportion of the working population of the worsted district; and they had been accustomed every few years to celebrate, with great stir and show, the anniversary of the martyrdom of the inventor of wool combing—their patron saint, Bishop Blaize. It was high time, however, for something to be done to rescue the comber from employment that was unhealthful and demoralising. His surroundings were of the most wretched character. Compelled to do his work in a small living-room or bedroom; breathing the noxious fumes of the charcoal with which his "pot" was heated, and of the oil which he had to sprinkle over his wool; and driven by the low rate of wages to live in small, poverty-stricken abodes, it was scarcely to be wondered at that he lashed himself into rebellion against mankind in general, and was always ready to ally himself with any body of agitators—social, political, or religious—whose aim was to work great and sudden changes. But when a really great and sudden change overtook the hand comber himself in his employment—when the time came for him to yield his labour to the superior competition of a machine—then he was conservative enough, and opposed the new power with unreasoning bitterness. He deprecated the change, and he deprecated the machine; but it was all in vain—the machine effectually asserted its supremacy, and in time hand wool combing was entirely obliterated, the discontented combers being absorbed into other occupations.

The story of this great invention will be duly told in another portion of this work—how by the untiring exertions of such men as Collier, Heilmann, Donisthorpe, Lister, Holden, Noble, and Hubner, the numerous wool-combing machines that are now in use were severally developed. In the present paper, however, we are only concerned with the machine which Mr. Isaac Holden now exclusively employs at his Bradford establishment, which we have undertaken to describe, and at the two large wool-combing concerns carried on by the firm of which he is the head, at Croix, near Roubaix, and at Rheims, in France. For upwards of forty years, Mr. Isaac Holden has been more or less associated with wool-combing inventions; first, with Messrs. Townend Brothers, at the Cullingworth Mills, then in conjunction with Mr. S. C. Lister and Mr. G. E. Donisthorpe, and more recently on his own responsibility. Mr. Holden was for many years in partnership with Mr. Lister, and managed the two concerns before referred to at Croix and Rheims; but in 1857 he purchased Mr. Lister's share in those establishments, and the present firm of Isaac Holden and Sons was thereupon constituted. Four years later, the Alston Woolcombing Works at Bradford were established, and from that time forward this firm have carried on the business of commission wool-combing at Croix, Rheims, and Bradford, on a very large scale. They have now by far the largest separate wool-combing works in the world, and each establishment is well entitled to be termed a "model" one.

The Alston Works are situated in Thornton Road, Bradford, a locality which has witnessed every successive development of the worsted trade. It was in that smoke-hued district where, in the year 1800, the first steam factory in Bradford was built, and where, from that time, there has been centred an ever-growing array of huge, many-windowed mills and towering chimneys. Here, the hum, and clash, and whir of machinery assail one at every turn; here, at early morn, and at closing time of an evening, thousands of factory hands may be seen trooping to and from their daily labour; and here, throughout every working day, wagons and carts, laden with "pieces," wool, or yarn, throng the road in all directions. The farther we proceed up this road, away from the town, the better it looks; the dingy, dirty, and cheerless edifices in which the worsted manufacture was cradled, are left behind,

The Alston Wool-combing Works of Messrs. Isaac Holden & Sons, Bradford.

and large, stately factories rise up on either side and give solidity and dignity to the thoroughfare. A mile or so away from the centre of the town, we come upon the Alston Works, and can at once see, by their magnitude and substantial appearance, that they perform an important part in sustaining the manufacturing eminence of Bradford. The ground occupied by the works—including yards, reservoirs, offices, and out-buildings—comprises eight acres. The great shed alone contains about six acres of flooring. Everything about the place tells of careful superintendence. There are no unsightly mounds of cinders, no scattered heaps of broken machinery, no tumble-down walls or unseemly projections; but there is an architectural harmony about the buildings which one does not always look for in structures designed for industrial purposes; and a commendable neatness and orderliness seem to surround the whole place. A suite of commodious offices, together with the residence of Mr. Thomas Craig, the managing partner, marks the Thornton Road boundary, to the right of the entrance gate; while, in a line therewith, on the opposite side of the gateway, there are certain weigh houses, miscellaneous offices, and stables. Looking across the yard, we see a couple of capacious reservoirs, and, beyond these, an engine house, where an engine of 50 horse-power is kept continually pumping water from a great depth. With that persistency of endeavour which is one of the chief characteristics of the modern pioneer of industry, Messrs. Holden determined to sink for water within their own grounds, and they went down and down until they had made a pit of enormous depth. After an expenditure of not less than £10,000, they succeeded in their search, and have now the command of a never-failing supply of water, of a quality much superior to the town's water, and with special mineral components, which render it of great value for the purposes of the wool-combing business. A branch railway in connection with the Great Northern system runs into the works, so that the facilities for the receiving and transmission of goods are very complete. The arrangements for the rapid execution of work, indeed, are as effectual as it is possible for them to be. Time is often of so much importance in these matters that nothing less than a perfection of system would have satisfied Messrs. Holden, and now, so closely are all their stages of wool combing dovetailed together, so tightly does one process fit into another, that they have probably attained the maximum of expedition. It is a frequent occurrence that a customer will buy a quantity of wool at the beginning of the London sales, despatch it to Bradford, and within a week Messrs. Holden have the wool combed and ready for delivery. Upon the result thus rapidly obtained, the customer, while the wool sales are still continuing, is able to regulate his further purchases.

The appearance of the Alston Works from the outside is that of a well-built, symmetrical, and gigantic stone shed, with the customary surroundings of chimneys, engine houses, offices, and workshops; the appearance of the interior is altogether different. Outside, a certain amount of repose seems to linger round the building, despite the buzz and clang of machinery; inside, a world of noise, glitter, and animation is revealed—wheels, pulleys, levers, cranks, and arms revolve, and chop, and slide, and rise and fall, with a firm and steady precision which no human action could equal; the stone floor, sturdy as it is, reverberates beneath one's feet, and on every side stand the evidences of a great and mighty force. From the wool combing of the hand comber, with his "pad post" and his "pot o' four," to the operations of these wonderfully constructed machines, is an advance as great as the ingenuity of man ever achieved at one step—a transformation as complete as it is well possible to conceive.

A glance at the different departments of the Alston Works, without attempting any exact description of the various processes of wool combing, may not be uninteresting. It is the only way to arrive at anything like a correct idea of the magnitude and extent of the establishment.

First, then, we descend into the large warehouse or cellar, which extends under the entire length and breadth of the shed. It is 390 feet long, and 270 feet broad, and is almost always full to repletion with bales and sheets of wool, just as they have been forwarded from the different customers. This vast storehouse is divided into thirteen separate compartments, or "rooms," as they are technically termed, which "rooms" correspond precisely to similar divisions in the shed above. By this divisional arrangement, each lot of wool is kept from first to last to its own series of "rooms." The "lot," to begin with, is placed in a division of the warehouse which is completely boarded off and separated from everything else; and the wool is then emptied from the sheets and despatched up its own particular hoist into the corresponding division of the wash-house immediately above. It may be imagined what a quantity of packs of wool is continually going through this warehouse when it

is stated that on an average about 170 bales pass in and out of the works every day. It is such a large warehouse, and there are so many jutting piles of wool, that the work-people in this department appear to be hidden away, and, as one walks through, voices seem to float up from cavernous depths in a most mysterious fashion. One side of the warehouse is entirely occupied with little railed-off courts for the reception of the incoming wool, and from thence it is passed forward up into the shed, where the first process of manipulation is brought to bear upon the fleeces.

From the receiving warehouse we see the wool sent aloft into the wash-house. Thither we follow it. The staircases and inlets we have to pass through are of the most roomy description, and we soon make our way by them to the ground floor. The wash-house is at one end of the building, and extends the entire length of the shed. It is sufficiently wide to admit of two rows of washing machines and tanks, and to allow for a moderately broad pathway down the centre, between the two rows. Such a washing and scouring one sees going on here! The wool is being dressed, and stirred, and shaken in tanks full of soapsuds by men armed with pitchfork-looking instruments. From the tanks it is passed through a series of rollers, and shaken and wrung in various ways until at last it emerges from the washing machines in a white and wholesome condition. All the way down the wash-house, on both sides, men are to be seen with shirt-sleeves rolled up, tossing their pitchforks about amongst the wool and the soapsuds, and the atmosphere is redolent of soap, and lather, and steam. Passing down through the wash-house, we get occasional glimpses of the great shed through the open archways, and can hear the sound of the machines high above all.

We slip under one of the white-washed archways, and find ourselves in the great shed—in the very heart of the machinery. In the space that here stands exposed to us there are no fewer than 117 gigantic carding machines, and 150 combing machines, besides a full complement of back-washing and gilling machines. The cards adjoin upon the wash-house; then comes the back-washing section; and finally, the combing and gilling; the thirteen original divisions being maintained throughout, in the same manner as in the warehouse below. The carding machines are kept running night and day, two relays of work-people being employed. During the day both males and females "mind" these machines, but at night only males are allowed to work them. The combs, however, are such delicate instruments, and require such tender handling, that females only are intrusted with their management — male fingers are considered too clumsy to have the handling of them. Hence arises the necessity for a double supply of combs, since night labour for females is against the law. This is the way in which the combing keeps pace with the cards. In France, females work by night as well as by day, so that the same proportion of combs as at the Alston Works is not required at the other two concerns kept up by Messrs. Holden. Thus, the combing processes are continued night and day, and except on Saturday afternoon and Sunday, the engines know no rest.

There is an elevated platform in the middle of the large shed, from which the whole of the interior can be taken in at a glance. Standing there, we survey with amazement the scene of activity which is spread out before us. First, after the wash-house, there is a breadth of carding machines —nine rows of them—stretching from top to bottom of the shed and buzzing and whirring as they attack the newly-washed wool. They take the fibre within their greedy jaws, break it upon their various wheels, rollers, and cylinders, shake from it all foreign elements and *impedimenta*, and, at last, the wool which enters the machines in tangled fleeces emerges therefrom in a white, film-like form, and appears to be another material altogether. A white mist seems to hang over the cards, but they are well fenced in, and seem to be almost automatic. After the cards, comes a line of two rows of back-washing machines; and, after that, the *ultima thule* of the wool-combing process is reached, and we see row upon row of these delicate instruments upon which so much human ingenuity has been expended —the combs themselves. As a piece of simple mechanism they are beautiful to look upon; the brightness of their appearance, the unerring precision of their movements, and the dexterity with which they handle the wool, combine to excite admiration. To such an extent are these machines self-acting that one girl can mind two of them with perfect ease. All she has to do is to see that the combs are kept strictly clean, and that no obstruction is permitted to interfere with the ingress and egress of the woolly fibre. The combs move round the machines horizontally, each comb forming a circular segment, and they are fed by a couple of feeders which imitate the motion of the old hand comber, and rise and fall with astonishing rapidity.

Looking across these bright rows of combing machines, this continuous rising and falling movement of steel-teethed instruments makes an exceedingly striking picture. The horizontal combs convey the wool round to the drawing-off rollers, and then we see the wool issuing from the machines in its combed condition—falling in white, lustrous, delicate filaments into tall tin cans placed ready for its reception. The grand operation is now complete. As the wool unfolds itself in gentle "slivers" from the machines, it lies with its fibres all tenderly smoothed out in one direction, and is cleansed from all impurities. It now only remains for it to be handed forward to the gilling machines, which amalgamate the long and short fibres, and roll the whole into convenient balls. The "tops" are now prepared for the processes of drawing and spinning, and ready for delivery. When made into "tops," the wool is launched into the warehouse recesses below, and from thence is despatched to customers. Tickets of a particular colour and number accompany each "lot" of wool through all the processes, thus securing perfect separation for it all through. Each ball of "tops" is delivered with its ticket on, and if anything were found to be wrong with it they could trace the fault to the very department where it occurred. With such an immense establishment, such a large number of delicate machines, and such a constant inflowing of work, the most systematic management is required, and, in this case, it is fully attained. Giving themselves up solely to the business of wool combing, and having had a vast experience in this country and in France, Messrs. Holden and Sons are enabled to arrange their establishments on the most improved principles. Their shed and other work-rooms are fitted up with all due attention to the health and comfort of their work-people, and are roomy, well ventilated, and scrupulously clean. In walking through the works one is not oppressed with unpleasant odours, nor are one's eyes offended by anything dirty, slovenly, or disagreeable. In the early days of combing machines, the places where they were worked were often extremely unhealthy, close-smelling, and over-heated, and it was not without some show of reason that they were termed "devil-holes" by those whose fate it was to labour in them. Now, all this has been changed, thanks to a better appreciation of the laws of health; and no firm has done more to bring that alteration about than that of Messrs. Isaac Holden and Sons.

In conclusion, it may be mentioned that at the Alston Works, when in full operation, 700 work-people are employed; that they have three steam engines of an aggregate horse-power of 1,100; and that, for power and heating purposes, they consume 40 tons of coal per day. They make all their own combing machines on the premises, and do all their own repairs, their machine and mechanics' shops forming a very important part of their works. At the three concerns over which Messrs. Holden preside there are 23 acres of actual flooring; they employ about 4,000 work-people, and run about 500 carding machines and 370 combs. The work which these combing machines can accomplish, would have taken no fewer than 25,000 hand combers to have done under the old system. The raw wool which yearly passes through these three concerns represents the produce of over 20,000,000 sheep.

As evidences of what can be achieved by great inventive skill, untiring industry, and singular business sagacity, the Alston Wool-combing Works are well worthy of notice. They are in every respect entitled to the name of Model Establishments.

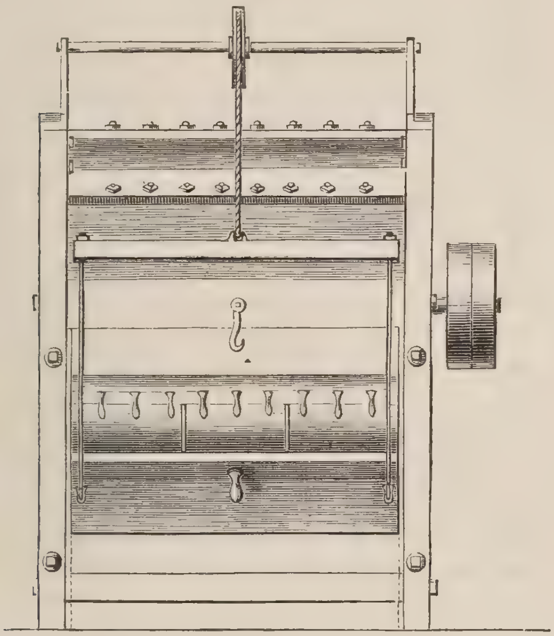
COTTON.—VII.

OPENING—SCUTCHING—CARDING.

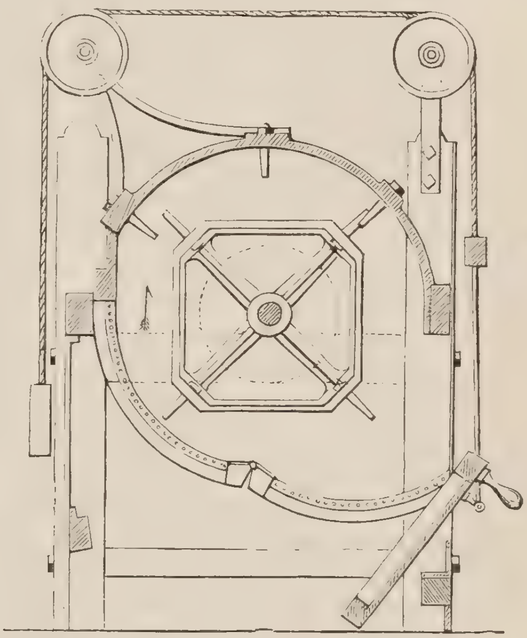
By David Bremner, Author of "The Industries of Scotland."

HAVING brought the history of spinning machines down to the production of Roberts's self-acting mule, it is now desirable that we should retrace our steps and note the progress made in those appliances by the aid of which cotton wool is prepared for spinning. The wool is imported in compactly-pressed bales weighing about 400lb. each, and as the process by which the seed is separated on the plantation leaves many impurities behind, the first care of the manufacturer is to subject the fibre to a succession of cleansing operations. In the early days of the cotton manufacture the broken seeds, leaves, &c., were removed by hand picking, and then the wool was spread on

the floor or a table, and beaten with willow wands, which had the effect of loosening the fibres and removing sand and dust. An improvement on this plan was the introduction of a table covered with a strong, close-meshed netting, which allowed the sand and other impurities to pass to the floor during the "willowing." The process was one that consumed much time, and the persons employed at it suffered seriously in health from the dust which they could not help inhaling. Towards the end of last century, after seeing how effectively mechanism could be made to perform much more complicated work, various persons turned their attention to devising means for superseding hand willowing. In 1801 Mr. Bowden patented a machine, in which a series of rods were brought to bear in succession on the wool in imitation of the action of the hand—or rather, hands, for the machine wielded the wands so vigorously that it was equal to doing the work of a dozen beaters. After delivering a blow, each rod was drawn horizontally backward by a sliding motion, and then raised to a vertical position ready to give another blow, which it was made to do by the sudden release of a spring. The machine was adopted in a number of factories, but it was always regarded as too violent in its action, and was readily discarded when a more perfect one was introduced. Its most formidable rival was the square-framed willow, which came into general use, and held its position until a recent period. This machine consisted of a cylindrical chamber about 3 feet in diameter, supported in a horizontal position in a stout frame of wood. The lower part of the cylinder was formed of an iron grating, and the upper part of a sheet of iron bearing on its inner surface three rows of strong spikes arranged longitudinally. On an axle which passed through the cylinder from end to end was fixed a square frame which bore on each of its angles a set of spikes similar to those in the cylinder, but so adjusted as to pass between them. A section of the lower part of the cylinder was made to open, and so give access to the interior. In using the machine, the workman in charge opened the doorway, tossed in a bundle of wool, closed the aperture, and set the axle in motion. As the spikes on the rectangular frame sped round, they caught up the wool in flakes, and by dashing it against the fixed spikes in the cylinder loosened the tangled portions, and disengaged the sand and other impurities, which escaped through the grid. After a given time, the machine was stopped, the cotton removed, replaced by another lot, and so on. The machine did its work fairly well, but the small quantity of wool operated on at a time, and the frequent stoppages necessary, proved serious drawbacks. The conical self-acting willow, invented by Mr. Lillie, of Manchester, was a great improvement on the machine just described. It consisted of a truncated cone formed of sheet iron and mounted on a horizontal axle. On its exterior surface were four rows of pegs arranged longitudinally. The cone was



Front View with the Door open.



Side Section.

THE SQUARE-FRAMED WILLOW.

inclosed in a casing of similar form, but about 6 inches more in diameter, so that there was a space of 3 inches all round. In the casing were rows of pegs corresponding to those on the cone, and the lower part of it was perforated so as to allow the dust to escape. At the narrow end of the cone was the feeding apparatus, which consisted of an endless apron on which the cotton was spread by hand in an approximately even layer, and drawn forward to the machine. As the cotton was caught by the pegs of the cone and beaten against those of the casing, it was, by the action of centrifugal force, gradually urged towards the wide end of the cone, where it was received upon a travelling apron and turned out upon the floor. In passing to the apron, it came into contact with a drum of wire netting, through which some of what dust remained among the fibre was drawn off by a current of air generated by a fan. This machine underwent modifications at the hands of various mechanicians; but its main features are retained in some of the willows—or "openers," as they are also called—still employed.

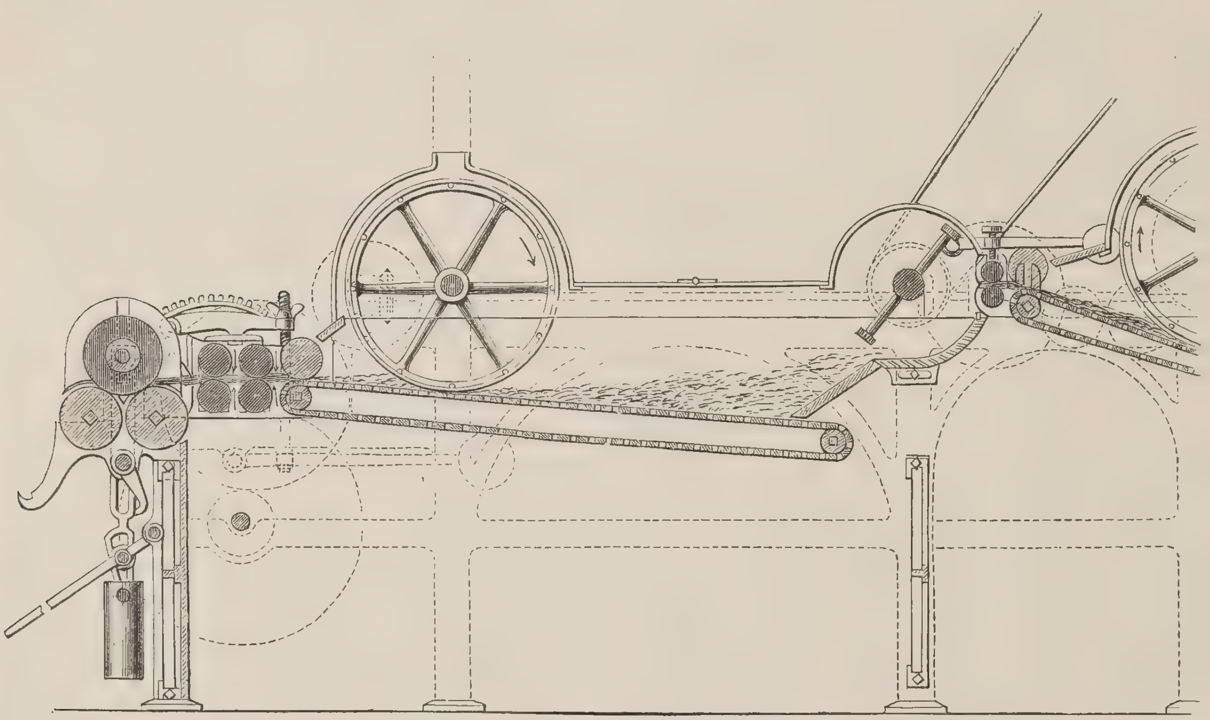
One of the most efficient openers in use, especially for dealing with coarse and badly-ginned cotton, is that which was invented during the civil war in America, by Messrs. Crighton and Co., of Manchester. At that time, owing to the interruption of supplies from the States, cotton of inferior quality found its way into the English market, and great difficulty was experienced in dealing with it. This led to the production of the machine referred to, which answered all requirements; and it still retains an important place among the appointments of a modern cotton mill. It consists of two iron chambers of conical form placed side by side, each resting on its apex. Each contains a series of beaters fixed on a vertical shaft and capable of being driven at a high rate of speed. The cotton is fed into the machine through a tube communicating with the lower part of the first chamber, and is there brought into contact with the beaters. As the beating proceeds, the cotton is forced to the upper part of the chamber, and makes its exit through a tube communicating with the lower part of the second chamber, in which it undergoes exactly similar treatment, and is ultimately thrown out in a fine fleecy condition, freed from a large portion of the impurities it contained when it entered the first chamber. In the bottom of each chamber is a grid communicating with a tunnel from which the air is being constantly drawn by a fan, and by this means the dust is removed. Messrs. Lord, of Todmorden, introduced a new mode of feeding openers of various kinds. A long tube, with its lower side perforated, is attached to the machine, and through this the cotton is forced by a strong current of air, the result being that a good deal of dust is got rid of before the cotton reaches the beaters.

Though the operation of the willow freed the cotton of the grosser impurities, it was found necessary to the production of the finer qualities of yarn that the cleansing process should be carried to a higher degree of perfection. The muslin manufacturers of the West of Scotland were the first to be impressed with this necessity, and in 1797 Mr. Snodgrass, of Glasgow, introduced to the trade a machine which realised, to a large extent, the wishes of the spinners. This was the scutching machine, in which the cotton was subjected to a more thorough beating than in the willow, and had the dust completely removed. The scutching machine was improved upon from time to time, and as now used leaves little to be desired in the quality of its work. Our engraving gives a sectional view of the delivery end of what is called the "first scutching machine." The machine in its complete form consists of a feed apron, two sets of beaters, two perforated dust cylinders, and an arrangement of rollers for delivering the cotton in a "lap." The feed apron is composed of narrow laths of wood fixed upon a pair of endless leather belts. It is divided into sections about 4 feet in length, and in feeding the machine a certain weight of cotton is spread on each section. The object of this is to secure an even supply of material to the scutchers. While one section with its load of cotton moves forward into the machine, the attendant weighs off another quantity of the "opened" wool, and spreads it over the next section, and so on. As cotton varies slightly in weight, according as the weather is wet or dry, and as a metal counterpoise is uniform, a variable counterpoise is made by packing with cotton, of the right weight for a feed, a cylinder made of wire gauze, in shape like a stable lantern; as this weight is about as much affected by atmospheric changes as the cotton which is to be weighed, an equality is thus preserved in forming the laps. From the apron the cotton passes between two wooden rollers to the feed rollers. The latter are of iron, and their surfaces are fluted for the better grasping of the cotton. Considerable importance attaches to the even feeding of this and the other preparing machines; and in addition to the provision made by weighing to secure this end, an ingenious

contrivance has been attached to the upper feed roller which insures what may be described as complete uniformity. This part of the apparatus is not shown in the drawing, but a brief description will make its operation easily understood. The upper roller is so adjusted that whenever more cotton than the desired quantity gets between it and its fellow, it rises, and in doing so moves a lever which operates on a belt connecting two conical drums; and the effect is that the motion of the apron is retarded to the extent necessary to restore the feed to uniformity. Should the feed become too thin, the upper roller is depressed, and, in this case, the effect produced is a quickening of the progress of the apron. The feed rollers conduct the cotton into a circular chamber in which the first pair of beaters revolve. The beaters consist of flat bars of iron attached to a horizontal axle, and are driven at the high speed of 1,500 revolutions per minute. As the cotton emerges from the feed rollers, it is struck by the beaters with such force as to disengage any dust or fragments of seed and leaf and loosen the intanglement of the filaments. In the under side of the circular chamber is a grid through which the heavier particles of dust escape. The beaters send the cotton flying into an inclosed passage, the bottom of which is composed of an apron similar to that by which the machine is fed, and on which it is carried forward to a perforated zinc cylinder, from which the air is being constantly drawn by a fan. Against this cylinder the filaments are impinged by the draft, the perforations not admitting of their passage, but allowing what particles of dust may have been retained among the fibre to escape. As the cylinder revolves, it deposits the cotton in an even layer on the apron, and in that form it passes to another pair of feed rollers, and another set of beaters which revolve at a higher speed than the first. This second beating effects a still further loosening and cleansing of the wool. On leaving the second division of the machine, the cotton is caught between two pairs of calendering rollers, by which it is pressed into a continuous lap, or slightly felted web. The lap is wound on rollers in quantities convenient for subsequent operations. That the fibres should suffer to some extent from this severe treatment is a matter of course, but the extent of the injury is not nearly so great as one would suppose. Several inventions designed to reduce the injury have been brought into notice, one of the latest being of American origin—the Whipper-Beater—patented by Messrs. Whitehead and Atherton. Instead of a single rigid rod, each beater is composed of six sections which swing freely on an axle, and inflict a soft and yielding blow to the cotton. Before it is ready for carding, the cotton has to go through the "second scutching machine," which is nearly identical with the first, except that it is fed with lapped instead of loose cotton. In a frame at the feed end, three or more rolls of lap are placed one over the other, and the wool from all of them is drawn into the machine simultaneously. If the mixing of various qualities of cotton, necessary to the production of certain kinds of yarn, has not been done before, it is usual to do it at this stage, by putting on the machine laps of the kinds of cotton it is desired to blend.

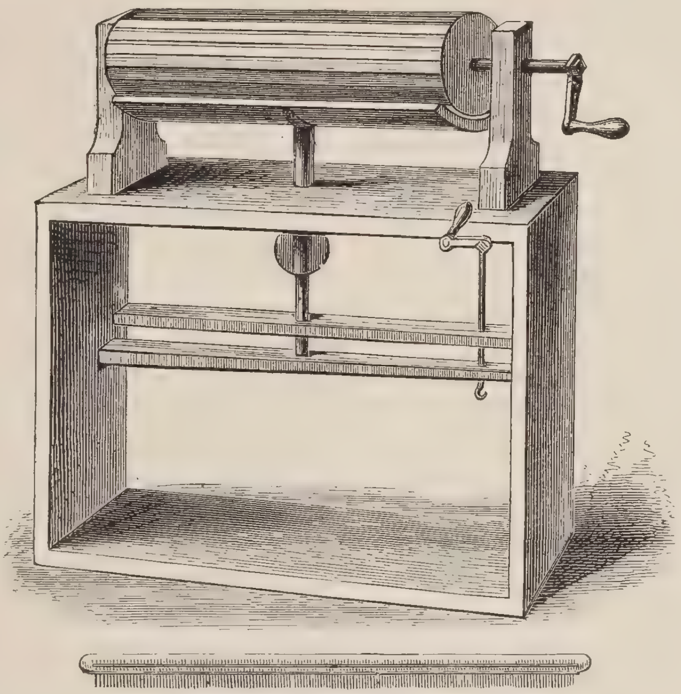
Having passed through the scutching machines, and been formed into a lap, the cotton is ready for carding. This process is a most important one, and much time and ingenuity have been expended on bringing it to the present degree of perfection. As originally conducted by means of hand cards, the operation was an extremely simple one, but the machines by which it is now performed are complicated and costly. The objects sought to be accomplished by carding are to disentangle the fibres as much as possible, and lay them parallel to each other. In early times, the cards were composed of rows of wire points stuck in a piece of stout leather in a sloping direction. The leather, which was usually about a foot in length by half that width, was fixed to a board with a handle attached. Taking up one of these cards, the operative spread on it a certain quantity of wool, and then by drawing another card over it again and again, pulled all the fibres straight, and finally turned off the wool in a fleecy roll ready for the spinner. One of the earliest improvements on this simple apparatus consisted in increasing the size of the cards, fixing the lower one to a bench, and suspending the upper by means of a cord and pulley. A larger quantity of wool could thus be dealt with at one time, and a considerable saving of labour was effected. To James Hargreaves, the inventor of the spinning-jenny, is given the credit of introducing cards of this kind—known as "stock cards"—to the cotton manufacture. As the demands on the carders were increased by the improvement of spinning apparatus, it was felt desirable that the carding should, if possible, be made a continuous process. In May, 1748, Mr. Daniel Bourn, of Leominster, patented a cylindrical carder, the first of which we have any information. About three months afterwards, Lewis Paul, of Birmingham, the inventor of

roller spinning, obtained a patent for two improved modes of carding. In the first of these, the lower cards were attached in parallel bands or fillets, with a small space between each, to a flat board. The description in the specification says:—"The card is made up of a number of parallel cards, with intervening spaces between each, and the matter being carded thereon, is afterwards took off each card separately, and the several rows or filliments of wool or cotton so took off are connected into one entire roll." The upper card, which was worked by hand, had fillets of wire corresponding with those in the lower one, and by working it in a peculiar way a roll of carding was produced from each band of cards. The second machine, though included in the same patent, was a great advance on this. It consisted of a cylinder covered with cards, which took the place of the upper card in the other arrangement; while for the lower one was substituted a curved card, so adjusted that its teeth worked in those of the cylinder. The lower card could be lowered from the cylinder to receive a supply of wool, and that having been put on, it was again raised into contact with the cylinder. A few turns of the latter were sufficient to arrange the fibres, and then the curved card was lowered and the wool stripped off it in rolls by means of a "needle-stick"—a comb made by fixing a number of needles in a slip of wood. In order to arrange the carding in continuous lengths to supply the spinning machines, Paul devised a system of belts or ribbons, which operated in this way:—A roller or bobbin containing a length of ribbon was placed beside the carding machine, and the ribbon led on to a second bobbin—the space between the bobbins being equal to the length of the cardings. As each carding was produced, it was laid on the ribbon, and the two were wound together upon the second bobbin; and so on. From bobbins filled in this manner, the carding was passed to the spinning machine in a continuous line. The combined operations here described displayed much ingenuity, and marked an important step towards what was subsequently achieved by other inventors. The defects of the cylinder carder were the want of means of continuous feed and delivery. Such as it was, however, the invention had strong claims to adoption; and yet the Lancashire manufacturers regarded it with shyness for a long time. Indeed, it was nearly twenty years after the date of the patent before the machine came into anything like general use. The original machine was used in the factory which Wyatt and Paul had erected at Northampton, and when that establishment was broken up, the carder was purchased by a Leominster hatter, who used it to card the wool required in his trade. Subsequently the machine was introduced into Lancashire by a Wigan manufacturer. Mr. (afterwards



Cotton Scutching Machine. *(Sectional View of the Delivery End.)*

Sir) Robert Peel was among the first of those who recognised the merits of the principle of the machine, and, seeing its defects, took means to remove them. He employed Hargreaves, the inventor of the spinning-jenny, to carry out his ideas. The machine thus produced consisted of two or three cylinders covered with fillets of cards; and after the cotton had been operated upon by these, it was removed in rolls with hand cards applied by women. This carder did not, however, realise expectations, and it was put aside. In the year 1770 or 1771, Arkwright turned his attention to machine carding, and succeeded in furnishing the cylindrical cards with both a feeding and a delivering arrangement. It was claimed by several persons that they had forestalled Arkwright in these matters, and when his patent of 1775 was disputed, evidence was adduced which showed that though the claimants had made some progress in devising mechanical carders, their machines had not assumed a practical shape prior to the date at which Arkwright had secured his inventions. A mode of continuous feeding of the carder by means of a revolving cloth or apron, was invented in 1772, by Mr. John Lees, of Manchester, and this was the origin of what is still an important part of the preparing machines. Arkwright's plan was to spread an even layer of wool on a web of cloth, and roll the two together upon a roller. The carder gradually unwound the cloth and fed itself from the fleece. The carded wool was removed from the cylinder by the "crank-and-comb"—a beautiful contrivance, which is retained in the most improved carding engines of the present day. By this apparatus the wool was stripped from the cylinder in a continuous fleece, which was reduced to the form of a roll or sliver, by being passed through a funnel a little distance in front of the cards. As it emerged from the funnel, the sliver was compressed by a pair of rollers, and then allowed to fall in coils into a tall tin can.



PAUL'S CYLINDER CARDING MACHINE AND NEEDLE-STICK.
(Specification Drawing.)

SHIP BUILDING.—VIII.

THE DECKS OF IRON SHIPS.

THE decks of ships furnish a remarkable illustration of the fact that progress in the art of ship building has frequently been accidental rather than the result of careful study or experimental investigation. It seems certain that the earliest vessels were "open" or undecked, like boats of the present day. Vessels so constructed could not, of course, venture on distant over-sea voyages, except at great risk: but there were other reasons for leaving such voyages unattempted; and it is curious to note that decks were not introduced at first to increase the seaworthiness of ships, but only to add to their power of accommodation. In war galleys, platforms were required near the bow and stern upon which the soldiers could stand and fight: but the central part—or "waist"—of the vessel was occupied by the rowers, and was left undecked. At length the desire to increase the number of soldiers carried by each galley led to the introduction of a complete deck from stem to stern; but the central part of the deck, over the benches of rowers, was made portable, so that it could be removed. Cimon, the Athenian commander, is said to have originated this idea of a complete upper deck, nearly 500 years B.C., but the arrangement did not rapidly pass from the galley to other classes

of ships. Up to the time of the Norman Conquest, most of the ships of North-Eastern Europe were either open, or partially decked. As longer voyages were undertaken, the advantages of a complete upper deck could not fail to become apparent, forming as it did a watertight inclosure of the space required for the accommodation of crew and cargo, as well as a valuable addition to the seaworthiness of a ship. Further, as the sizes of ships increased, the necessity arose for intermediate decks to be used as platforms for carrying purposes, and for accommodation; and so by gradual stages an arrangement was reached which not merely fulfilled its primary purpose, but formed an important feature in the structural strength.

The usefulness of decks as structural strengtheners was scarcely recognised a century ago: and until iron ships of large size became common the full advantages derivable from carefully constructed decks were not realised. Now it is a generally accepted principle of construction that the decks, and especially the upper deck, should be classed amongst the principal parts of the structure, effective against strains tending to alter the form of a ship either longitudinally or transversely. Longitudinal bending in a ship—"hogging" or "sagging," as a shipwright would say—can only result from an extension or compression of the upper and lower parts of the structure; and ordinarily it is the upper deck which has to sustain the most severe tensile or compressive strains. Comparing a ship to a hollow tubular girder, like the Menai Bridge, her upper deck corresponds roughly to the top of that girder; her bottom, from the bilge downwards, corresponds to the bottom of the girder; while her nearly vertical sides correspond to the side webs of the girder connecting the top and bottom. There are, however, a few important differences between the ship and the bridge. In the latter all the bending strains tend to stretch the bottom and compress the top; whereas in the ship there are great *variations of strain*, the top being sometimes compressed and at other times stretched. The bridge is fixed in position, the top and bottom not changing their relative positions; but the ship rolls from side to side while she is being strained, and it is impossible to define absolutely what parts shall be regarded as the top and what as bottom. Moreover, the circumstances sketched for the ship obviously create simultaneously transverse as well as longitudinal strains, a matter which still further complicates the problem. A deck, for example, may not merely have to act as part of a girder resisting longitudinal bending, but at the same time may have to tie the two sides of a ship together, and assist in preventing change of transverse form, in addition to acting as a platform carrying heavy weights of cargo or equipment.

This summary of the manifold duties and uses of the decks in a ship will probably be new to many readers; for it is natural to regard the decks in their primary capacity as platforms, and to consider the beams merely as supports to the platforms, and the weights carried thereon. Such an incomplete view of the subject, although natural, could not fail to lead to imperfect construction; but it is only proper to add, in justice to the builders of earlier ships, that experience has been the great teacher of the broader and sounder views exemplified in ships of the present day. The substitution of iron for wood as the material chiefly used in ship building has also enabled the builder to simplify the construction of decks, as well as to make them more efficient.

Passing from these general considerations, it will be desirable to explain briefly, a few technical terms used in connection with the decks of ships. Every one is familiar with the fact that the decks of nearly all ships are curved both longitudinally and transversely. The longitudinal curvature is termed the "sheer," and it results in placing the fore and aft ends of the deck at a higher level than the midship part. This sheer is purely a matter of appearance, adding to the gracefulness of the form of a ship, particularly when there is a line of "ports" or openings in the side, which the eye of an observer can trace. In some few ships, as in the *Great Eastern* and some turret ships, there is no sheer: in other cases, as in the well-known "billy-boys," the sheer is extremely great; and with very low decks amidships a considerable height of freeboard is secured at the bow and stern, together with a valuable addition to the buoyancy and seaworthiness. Considerable sheer in a deck has been often asserted to be necessarily an element of weakness against longitudinal bending strains; and in a few ships this opinion has been carried so far as to induce builders to give a reverse curvature to the deck, making the extremities lower than the midship part. In a properly constructed ship the sheer of a deck need not be a source of weakness, and (as already remarked) the appearance of a vessel is thus greatly improved. Special cases occur, of course, where appearance is a minor consideration: and, as one of these exceptions, may be mentioned shallow-draught vessels for river navigation, where the

deck ends have been made lower than the middle of the length, in order to reduce the weight of the structure.

The transverse curvature of a deck nearly always gives it a considerable convexity, the main purpose of which is to readily and rapidly clear the deck of water that may lodge upon it. The deck is maintained in this form by means of the beams, which cross the ship transversely, and are bent or fashioned to the proper "round-up" before being put in place. Here again a popular notion associates the curvature with considerations of strength; and it is frequently asserted that the *arched* form of the beams adds to their strength. It is scarcely necessary to say that the comparison of deck beams to an arched bearing is most misleading, seeing that the sides of the ship cannot supply to the beams that resistance to their "thrust" which is supplied by the strong, fixed abutments of an arch. The beams have, in fact, to act as ties or struts, as the case may be, between opposite sides, and are therefore not merely supports to the decks and the loads they carry, but completions of the transverse framing which stiffens the skin, and which has been described in a previous chapter. Similarly, it is noteworthy that the pillars fitted underneath the beams are most valuable adjuncts, not merely as supports to the decks, but as contributaries to the transverse strength. In an iron ship these pillars not merely hold the deck beams up, but under some circumstances, when a ship is rolling at sea, actually do the opposite, and hold the beams and decks down, when the straining forces incidental to rolling motions tend to distort the transverse form.

Various sectional forms of iron beams and pillars have been illustrated on page 181, and remarks have been made on their manufacture. To these it may be interesting to add a brief description of the process by which the "beam knee" is formed, as it illustrates the greater ease and efficiency resulting from the substitution of iron for wood. Knees to beams are required where the beam ends abut against the sides; because as a ship rolls there is great danger that a change of angle may take place between the deck and the side of the ship, such a change of angle, of course, involving working and more or less distress in the structure. The diagram (Fig. 1) illustrates the three steps by which an iron beam knee is commonly formed. First, the beam end is cut along for a portion of its length near the middle of its depth; second, the lower part (*a*) is bent to the required outline for the beam knee; third, a piece of plate is welded in between the two parts (shown stroked across in the third step), and this completes the knee. Its attachment to the transverse frames has already been illustrated

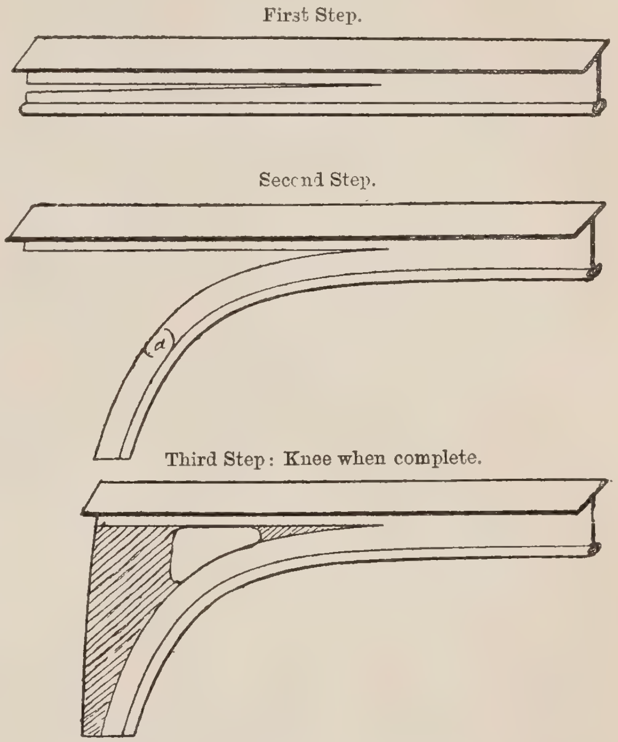


Fig. 1.—Construction of an Iron Beam Knee.

in the sectional drawing of an iron ship on page 185; and it will be obvious at a glance how efficient this simple arrangement must be. The attachment of the deck to the sides is still further strengthened by means of a longitudinal "stringer plate" (also shown on p. 185), which extends along the beam ends, and is riveted to the beams and to the outside plating. Contrasting this with the corresponding features in a well-built wooden ship (illustrated by Fig. 2), the superior efficiency of the iron ship will be apparent. A forged iron knee (*a*) is fitted underneath the beam (*b*), the end of which rests upon a longitudinal shelf-piece (*c*), and is held down by another longitudinal timber, the "water way" (*d*). The vertical arm of the iron knee is bolted through the planking and timbers of the ship's side, and the horizontal arm is bolted through the beam itself. This plan is the best which many centuries of experience with wood ships could evolve; and it answers fairly well. But even with it, working and change of angle between the deck beams and the side was not at all uncommon in a sea way; and every one familiar with wood ships will know how frequently beam-knee fastenings require attention and repairs. In addition, it will be clear that the work at the beam arms of wooden ships

must be much more complicated and expensive than the corresponding work in an iron ship.

At the outset of iron ship building, iron beams were only procurable with difficulty, and wooden beams were often fitted; in fact, the decks were arranged much as was usual in wooden ships. This defective system was, however, speedily abandoned: iron beams of a flanged section replaced the solid rectangular timber beams, iron pillars took the place of wood, and iron deck stringer plates were fitted instead of wooden water ways. All these changes tended to produce greater rigidity in the structure, and a fuller association of lightness with strength. The plan now in general use for beam-end connections has every chance of remaining undisturbed, for it answers its purpose admirably, and it is not easy to see how it can be greatly improved upon. One attempt at improvement has been made in ships framed on the longitudinal system (illustrated by the sectional view on p. 205), where it will be observed that the deck is supported by bearers placed longitudinally, instead of by transverse beams. The principle of this altered arrangement of deck-bearers is identical with that previously explained for the longitudinal system of framing—viz., that the stiffeners to the decks should be capable of assisting the decks in resisting the longitudinal bending strains, which are the most important strains sustained by the structure. But while the principle is a sound one, its application to decks has never found much favour, and most ships with longitudinal framing have their deck beams placed transversely. In fact, it will be obvious that unless the bulk-heads extended to the upper deck of a ship, and formed supports to the longitudinal bearers, they could not be used successfully; and it is not usual to carry the bulk-heads up to such a height except in small vessels. Another plan which has been used in a few iron ships, framed on the *diagonal* system, consisted in placing the beams diagonally across the deck instead of transversely; but this involved many inconveniences, and possessed no compensating advantages. The iron ship builder has very little work to do in the preparation of the deck beams; in fact, the manufacturer not unfrequently supplies the beams to the correct lengths and "round-up," with beam knees completed, and ready to go into place. In other cases, the beam knees are formed in the ship-yard, and the beams are bent to their proper forms by means of suitable machinery, even when they are supplied of the desired sectional form. When "made" beams are used, formed of plates and angle irons, the builder commonly procures the several parts from the iron maker, and combines them himself into the finished beams. Such beams are, however, used less commonly now than they were in the earlier days of iron ship building; and the marked tendency of the times is to make fuller use of finished sectional forms, reducing the preparatory work to be done in the ship-yard. With wood beams no similar saving of labour is possible; by the skill of the shipwright, aided perhaps by saw-mill machinery, the beams must be fashioned out of the rough logs. Each beam must be made of two or three pieces in a ship of even moderate size; whereas, with iron beams, even for the largest ships it is possible to weld them into one length, or to roll them in one length without welding. The "scarphs" which are formed to unite the several pieces of a wood beam, require to be accurately fashioned and carefully fitted. One of the best plans of scarphing is illustrated in Fig. 3. The ends of the adjacent pieces are trimmed so that they shall "hook" into each other when superposed; hence this is termed a "hook scarph." Metal wedges or "keys" (*k k*) are driven in, in order to tighten up the scarph, and it is further secured by means of through bolts, and wood plugs or tree nails. By these elaborate and expensive arrangements

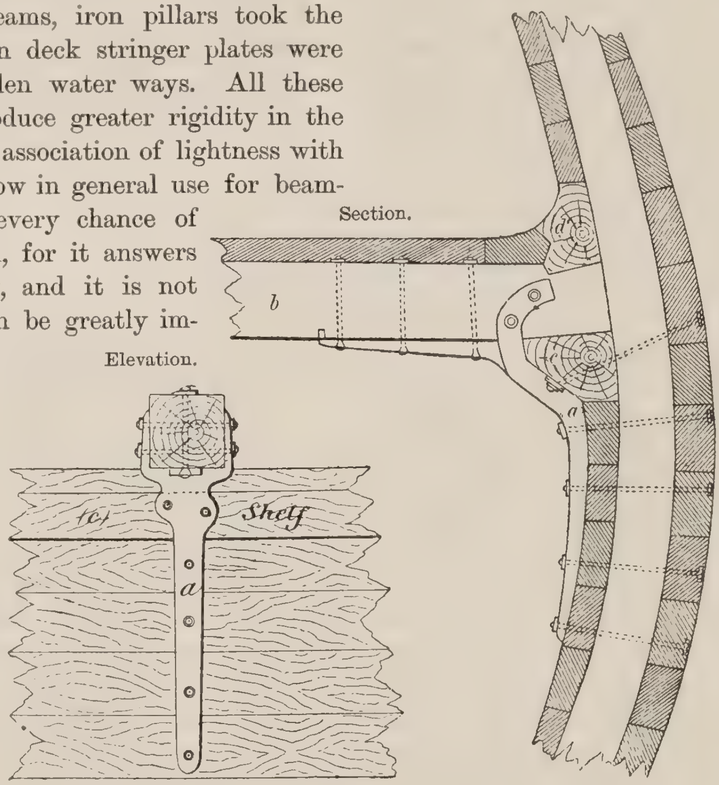


Fig. 2.—Construction of a Wood Beam Knee.

a combination is formed capable of resisting strains tending to pull the two scarphed pieces asunder, or to make them separate when the beam

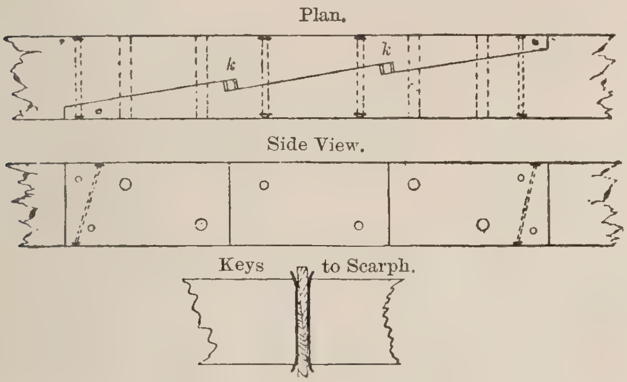


Fig. 3.—Scarph of Wood Beam.

is subjected to bending movements, produced by heavy loads. But even then the scarph is inferior in efficiency to the "weld" or other simple connection practised with iron beams. It is not surprising, therefore, that iron beams are now frequently fitted in wooden ships.

Passing from the beams or supports of a deck to the planking or plating that constitutes the platform proper—the "flat of the deck" or "deck flat"—a brief description must suffice. In most cases the deck flat is formed of wooden planks, placed longitudinally, and secured by screw bolts either to the upper flanges of the beams, or to the iron plating, now commonly fitted upon the beams and under the wood planking. In some iron ships there is no wood planking on certain decks, but the flat is formed entirely of iron plating riveted to the flanges of the beams. Fig. 4 illustrates the arrangement and fastenings of such an iron deck, and there is no important difference in these, whether the iron plating is covered with wood or not. A wood flat is fitted upon a complete iron deck not because it is necessary as a strengthener, but because it adds to comfort or convenience in the after-service of a ship, especially if she carries a large number of passengers or crew. In a cargo-carrying vessel these considerations have less weight, and the wood deck is sometimes omitted. In war ships also, where thick deck plating is used for defensive purposes, it is not unfrequently left uncovered.

A well-arranged wooden deck possesses considerable strength against the tensile or compressive strains due to longitudinal bending. But it cannot compare in efficiency with an iron deck, either complete or partial. At first iron ships had only wooden decks, or such decks associated with a few strakes of iron plating, stringers, tie plates, &c. But as the lengths and sizes of ships have been increased, greater strength has been needed in the upper decks, and the extent of the iron plating has been gradually increased, with such beneficial results that it is now customary to have at least one deck iron plated in ships of large size. The great Atlantic steamers, 400 or 500 feet in length, have in some instances the two uppermost decks covered with iron plating, worked under wood planking. Similarly, two completely plated decks are to be found in many iron-hulled, armour-clad war ships; and in the *Great Eastern* a still more remarkable arrangement is carried out on the upper deck, and will be described in a future chapter. So marked are the advantages of iron deck plating that in large wooden vessels of recent date it is not unusual to find the upper deck beams made of iron, and covered with iron plating as a corrective to the weakness of the upper works

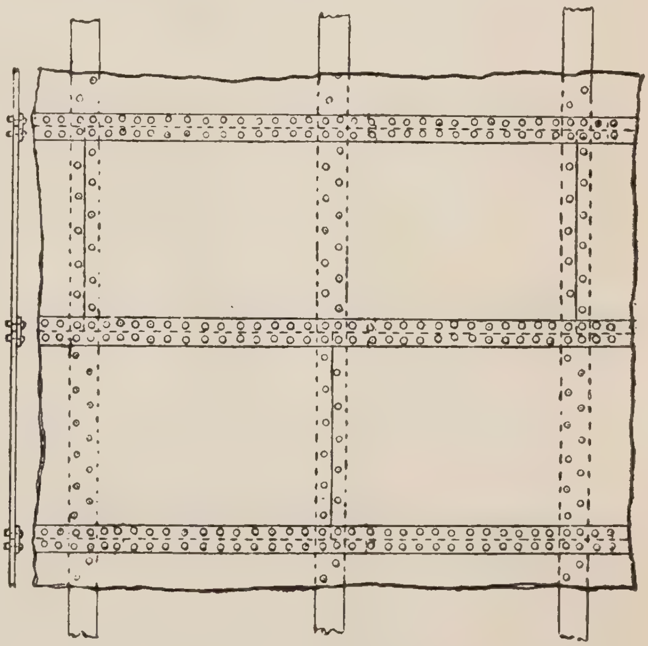


Fig. 4.—Iron Deck Plating.

commonly experienced on wood-built ships. Something of this kind has been done in the larger armoured wooden ships of our own and foreign navies.

Reverting to the comparison of a ship to a tubular girder like the Menai Bridge, it will appear that the uppermost deck is that which will be most strained by "hogging," or "sagging," and which consequently should have the greatest strength given to it. This reasoning applies to most classes of ships, and it leads to the further

conclusion that it is of the greatest importance to maintain the *continuity of strength* in the upper decks from end to end. There may, of course, be erections above the upper deck, such as poops, forecastles, deck houses, &c.: but these must be regarded as appendages to the structure, introduced for convenience sake, and not contributing any important assistance to the general structural strength. Below them all, and carrying all, should be found the strong continuous upper deck. In no particular, perhaps, is the difference more marked than in this between the practice of earlier times, and that of the present time. Take for example the French ship of the seventeenth century illustrated on page 93. A deep "waist" amidships marks the height of the upper deck proper. Above this comes a partial deck, running through a portion of the length from the stern, and known as the "quarter-deck." Above this, again, stands the "poop," and still higher, on another step as it were, is the "round-house." At the bow, similar, though less burdensome, superstructures were raised, culminating in the "forecastle." All these features were only "survivals"—to use a modern but expressive phrase—of the features which had been valuable in ancient types of war ships, before cannon were extensively employed, and when it was advantageous in naval engagements to have many men carried high up, where they could do most damage to an enemy when fighting at close quarters. But it then required a bold man to introduce any changes in ship construction, or departures from an established practice; and even to the end of the last century much of this top-hamper continued to exist at the extremities of our war ships. Their least depth occurred amidships—in the waist—where the greatest strength was required; and only a glimmering idea of the true functions and uses of a complete upper deck existed in the minds of a few of the most enlightened ship builders. All this is now changed, and changed for the better.

HEMP, FLAX, AND JUTE.—VII.

FLAX HACKLING—EARLY MODES OF SPINNING.

By David Bremner, Author of "The Industries of Scotland."

FLAX, as we have seen, is scutched in the localities where it is grown, and having been packed up into bales or bundles, is sent to market, where it passes into the hands of the spinners. In the spinning mill, the first process to which the flax is subjected is hackling, the object of which is to separate the filaments, remove knots, and give to the fibres a parallel arrangement. The hackle, in its simplest form, consists of a series of steel spikes fixed in a board attached to a table or stand, and is used by the workman drawing over it a bundle of scutched flax of convenient size. At each drawing, some of the coarser fibres and dust are separated, and gradually the longer and finer filaments are reduced to a silky state. This fine portion of the flax is called "line," and is used for the production of yarns of the highest quality, while the coarse fibre which has been extracted is called "tow," and is fit only for being worked into inferior yarns. The skill of the hand scutcher depends on the quantity of fibre of the best quality he can extract from a given quantity of flax. As in other departments of textile manufacture, machinery has to a very great extent usurped the occupation of the hand hackler. For some purposes, however, the old mode of operation is preferred; but obviously this can be for a time only, as the gradual improvement of the machines is certain to result one day in a degree of perfection in working that will quite surpass the action of the hand. The hackles employed are usually from four to six in number, gradually increasing in fineness of spikes; and the workman draws the flax over them several times in succession. He begins by taking up a quantity of flax about five or six ounces in weight, seizes it about the middle of its length, and twists the end towards him about his wrist, so as to maintain a secure hold of it. He then, by a peculiar turn of the arm, spreads the flax over the spikes and draws it through them. He operates on the root-end first, and having combed it out, presents the other end of the fibre. This he repeats on each of the hackles, until tow ceases to come off in any appreciable quantity, and then the dressing is considered complete. In order to soften the fibre, and make it finer, it is sometimes beaten with a mallet between the first and second hacklings. For this purpose a single twist is put in the middle of each

tress or bundle, and the twisted part is laid upon a block of wood and struck with a mallet. The twist is then undone, and the flax rubbed between the hands. Brushing at this stage is also regarded as advantageous. This is done by laying the flax on a board, and applying to it a brush made of swines' bristles.

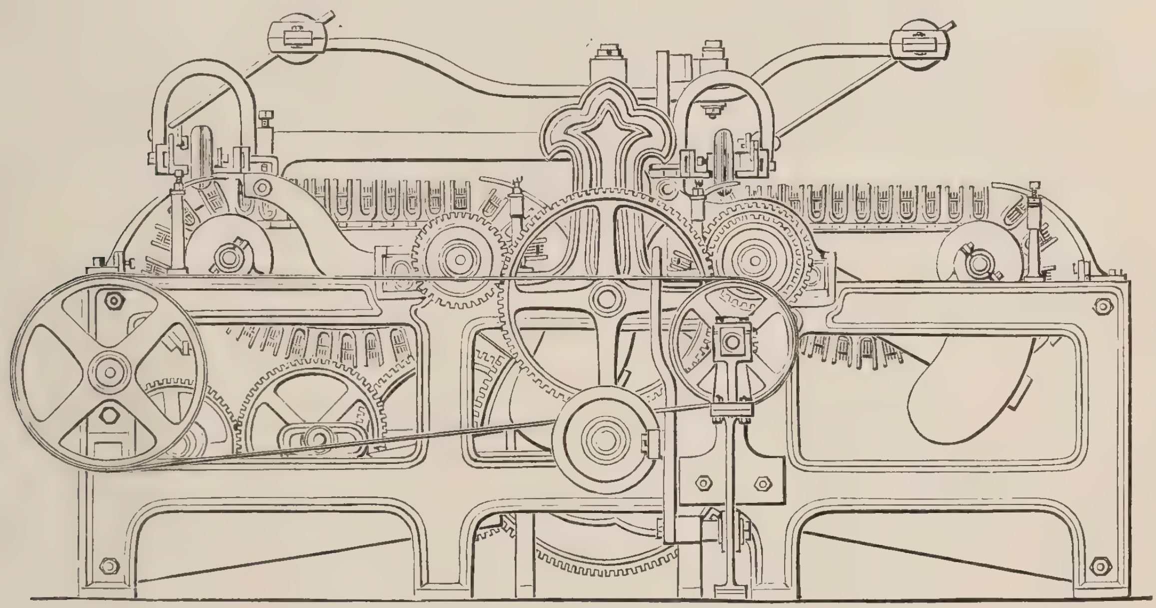
So much of the value of the fibre depends on the manner in which the hackling is done, and the operation is guided so much by the sense of touch in the workman's hand, that it was long believed to be an utter impossibility to accomplish the work by mechanical means. There were not wanting, however, inducements for inventors to attempt to produce a hackling machine, nor for mill-owners to adopt it, should it be produced; and about seventy years ago some ingenious person succeeded in imitating in mechanism the motion of the hackler's arm. This machine was called the "Peter," and was introduced into a number of factories. It consisted of a drum mounted on a horizontal axle, and carrying on raised parts of its circumference four sets of hackles. Over the drum was a projecting arm jointed to the frame of the machine, and made to rise and fall alternately by means of a crank. The flax to be operated upon was fixed in a clamp, and placed on hooks at the extremity of this arm; and as the cylinder revolved, the flax was struck down upon each set of hackles, and held firmly while they passed through it. As the hackles on each machine were all of one size, it was necessary to pass the flax over four or five machines, and thus present it to hackles increasing in fineness. The arrangement was hardly an economical one, but it was accepted as a forecast of what was believed to be possible in course of time. In 1825, the pendulum hackling machine was invented. It consisted of a compound arm and cranks which imitated the action of the hand even more perfectly than the "Peter." In the first form of the machine the hackles were fixed on a table, and the tuft of flax being dealt with had the successive sets presented to it by moving the table along under the machine. The flax, as in the case of the "Peter," was held in a clamp, which was placed on hooks at the end of the arm, and by the motion of the cranks it was drawn first to the right and then to the left over the spikes, so that both sides of the tuft were operated upon without turning the clamp. The machine was much improved by the substitution for the table of a frame similar to the cylinder of the "Peter," and carrying on its surface four sets of graduated hackles. When the flax had been drawn over the coarser set a sufficient number of times, the cylinder was turned round, and the second set of spikes brought into position, and so on. It will thus be seen that the flax once placed in the machine did not require to be shifted in any way until one of its ends was completely dressed. When this was done, the clamp was unfastened, and the second end of the tuft presented to the machine. The next noteworthy step in advance was the production of the sheet hackling machine, which introduced a principle still retained in the most approved mechanical hacklers. The hackles in this case were fixed upon an endless belt or apron, which travelled over a pair of rollers placed a little way apart; and the flax was held by an immovable arm, the clamps being turned as the work proceeded. Though the special feature of this machine was generally admired, there were defects in its working which hindered its general adoption. The improvements that had taken place in flax-spinning machinery about the year 1830 led to the practice of dividing the flax fibres into lengths suitable for the production of different qualities of yarn. The part nearest the root is coarse and strong, the middle part fine and strong, and the tip fine but not strong, and it was considered advantageous to use these parts separately. As a square end would not admit of the production of an even thread, means were devised for tearing the fibre asunder. For this purpose a machine is now used, which accomplishes the work at a rapid rate and in a satisfactory manner. In the case of flax of second or lower quality, intended for coarse yarns, no cutting is deemed necessary. The cutting of the fibre necessitated the contrivance of a machine capable of hackling the short lengths. Among the machines constructed to meet the new order of things was the circular or eccentric hackler, as it was indifferently called. In it hackles were arranged on a cylinder which revolved at a steady pace. At either end of this cylinder was a wheel a third larger in diameter, but so mounted that its axis was several inches to the rear of that of the cylinder. In the rims of these wheels were notches, and the long clamps holding the flax were placed with one end in a notch of each wheel. As the clamps were placed in position at the rear of the cylinder, the flax did not touch the hackles; but as the carrying wheels moved slowly round, they carried first the tips, and then the body of the fibres of flax into contact with the spikes. The machine was so adjusted that the hackle cylinder

travelled at a speed sufficient to enable it to do its work thoroughly while the carrying wheels made half a revolution. On reaching a certain point of the circuit, a self-acting shunt removed the clamp from the machine, when the attendant reversed it, and placed it again in the carriers to have the second side of the tuft dressed. As there were several clamps on the machine at a time, the amount of work accomplished was considerable. The tow was removed from the hackles by a brushing cylinder in the lower part of the machine. Only one size of hackle could be used, and it was the apron. Above the apron is a rail along which the clamps with their depending tufts of flax travel. The machine is fed at the side where the coarsest hackles are, and the clamps are thence passed along to the finer bands of spikes in succession. The number of clamps on the machine at one time corresponds to the number of the sets of hackles, and in passing through the machine each tuft of flax receives eight combings. How this comes about will be made apparent if we follow the course of one tuft through the machine. It is first slid along the rail until it comes above the coarsest set

HAND HACKLERS.

therefore necessary to put the flax through other machines having finer and finer hackles in succession before it could be thoroughly dressed. Besides the expense entailed by the necessity for having several sets of machines, the arrangement involved a great loss of time, and many attempts were made to devise a machine that would complete the hackling with one feeding. Among those who succeeded in a large measure were Mr. Carmichael, of Dundee, and Mr. Combe, of Belfast. Mr. Carmichael took as the basis of his machine the clamp system and travelling apron of earlier inventors, but used them in a much improved fashion. The apron is mounted on rollers so arranged that it presents a flat sloping surface in the front part of the machine. The hackles, instead of being of uniform dimensions, are of four sizes, each size being placed on a separate longitudinal section of of hackles, and is there held firmly for a few seconds, when suddenly it is drawn up some distance and turned round, so as to bring the other side of it into contact with the hackles. When this side is done, the rail rises, and the clamp is slid one stage to the left, where it brings its burden over the second and finer set of hackles. Here the holding and turning we saw in the first stage are repeated; the same takes place over the third and fourth sections of the apron; and, finally, the flax emerges completely hackled, so far as one half of its length is concerned. The clamp is then unfastened, the ends of the flax reversed, and the clamp again passed to the feeding side of the machine. When the flax has traversed the machine a second time, the hackling is complete. Among Mr. Combe's inventions is a machine in which the hackles are arranged in graduated bands

on a cylinder, and instead of turning the clamps when the second side of the tufts has to be dressed, that is accomplished by raising the flax for a moment, and reversing the motion of the cylinder. Mr. Combe has embodied the same idea in his patent reversing sheet hackling machine, which has found considerable favour in the eyes of flax spinners. In this machine there are two aprons, carrying hacklers which travel in a horizontal position. The flax is fixed in clamps, as in other machines, a row to each apron; and after one side of a tuft has been dressed, the clamps are swung forward to the other end, where (the motion of the aprons having in the meantime been reversed) the second side is brought into contact with the hacklers. The form of this hackler is clearly shown in the engraving. Other hackling machines might be mentioned—notably, that invented by Mr. Lowry, of Manchester—but the principle of their action may be sufficiently gathered from what has been already written.

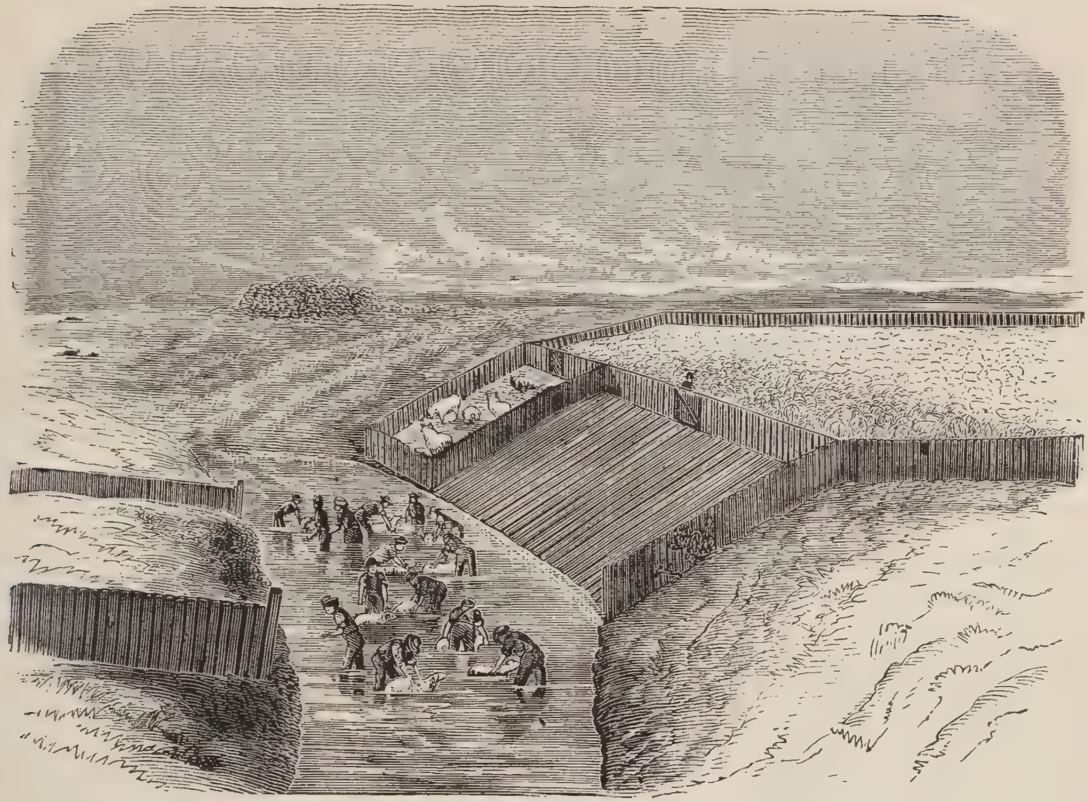


Combe's Double Apron Flax Hackling Machine.

After being hackled, the flax is ready for spinning, or rather for being passed through certain machines which arrange it in a form convenient for being spun. Flax spinning is one of the most ancient of arts, and yet it is remarkable that no improvement was made in it until a comparatively recent period. The distaff and spindle seem to have been regarded as the perfection of spinning appliances for three or four thousand years at least, and the way in which flax was spun in this country till well towards the close of last century, differed not a whit from that which prevailed in Egypt at the earliest period of which we have any record. It is true that in the fourteenth century a frame was devised for holding the distaff and enabling the spindle to be used to greater advantage, and that about the middle of the sixteenth century a spinning wheel was invented at Brunswick, and introduced into England; but persons who had been taught from their early youth to use the distaff and spindle, declined to sink their skill and experiment with the new apparatus, and the consequence was that many years passed before the merits of the wheel were fully recognised. Mr. Warden gives the following description of the use of the spindle, as practised in Scotland about a hundred years ago:—"The distaff was a piece of light wood, 15 to 20 inches long, round which the flax to be spun was wound, leaving a portion of the distaff clear of the flax. This portion was stuck into the apron-string of the spinner, or into a belt fastened round her waist to receive it. The distaff slanted out from the left side of the spinner, so as to be convenient for drawing the flax from it in forming the threads. The spindle was a round piece of wood about a foot in length, thick in the middle and tapering towards each end, the lower one something like the point of a cone, and the upper longer and less pointed, with a ring or belt of some heavy substance round the middle. A short thread formed of the flax was fixed in a notch in the upper end of the spindle, and the spindle was then turned smartly by the right hand

pressed upon it against the right thigh, and allowed to dangle in the air, hanging by the thread from the distaff. The centrifugal motion thus given to the spindle was kept up for some time by the heavy ring upon it, which acted as a kind of balance-wheel and kept the circular motion somewhat steady. While this whirling of the spindle was going on, the spinner was busy drawing out the fibres of the flax from the distaff with the left hand, and forming them into an equal thread with the right. When the spindle reached the ground and stopped, or when the impetus given to it by the hand was lost—care being taken not to let it retrograde, as by that means part of the twist given the thread spun would be lost—the yarn spun was wound upon the upper part of the spindle. The same process was repeated again and again, until the spindle was full, from one to two yards being spun at each movement given to the spindle. The yarn was then reeled off into cuts, heers, hasps, and spindles, when it was ready for the market or for being woven into cloth. This primitive system of spinning would appear strange to either maid or matron of the present day, but it was well known in Scotland to the grandmothers or great-grandmothers of this generation. It was sometimes practised within and sometimes without doors, as the spindle and distaff could be easily carried about, and it was no uncommon sight to see a girl herding the cows and plying her spindle busily the while. All females were thus taught to spin in their girlhood, and with care and assiduous application, but not without both, became expert at it."

Besides the prejudice in favour of retaining a mode of spinning which had been practised from time immemorial, the cost of a spinning-wheel, as compared with that of a spindle and distaff, was so great as to prevent many persons from adopting it, and its introduction into our textile manufactures was, as already hinted, a slow process. In course of time the spindle and distaff were driven from the field, and spinning on the wheel came to be regarded as a necessary female accomplishment. A great impetus was given to the use of the wheel by the operations of the Board of Trustees of the Linen and Hempen Manufactures in Ireland, and the Board of Manufactures in Scotland, who established spinning schools, and fostered competition in the quality of the yarns produced. It is recorded that in the year 1764 a great improvement in the spinning-wheel was invented by a Mr. Harrison, whereby it was said "a child may spin twice as much as a grown person can do with the common wheel." What the nature of the improvement was does not appear, but it was considered worthy of a grant of £50 from the funds of the Patriotic Society for the Encouragement of Arts and Commerce. At that time cotton was the fibre that was engaging most attention, and the minds of mechanicians were almost wholly occupied in contriving machines to work it. The marvellous achievements of this period are recorded in another part of this work, and require but a passing allusion here. When it was discovered to be practicable to spin and weave cotton by machinery, the case of other fibres naturally fell to be considered, and in the year 1787 it was made known to the world that the problem of spinning flax by machinery had been solved. John Kendrew, optician, and Thomas Porterhouse, clock-maker, both of Darlington, patented in that year "a machine, upon new principles, for spinning yarn from hemp, tow, flax, or wool." The inventors established a small factory on the river Skerne, at Darlington, and at once entered upon a lucrative business. Their machines were of a very simple character, but did their work fairly well, and requests for licenses to use them poured in from many quarters. Fortunes were being made by the use of machinery in the cotton manufacture, and persons who were engaged in the flax trade thought they had only to procure the new machines to insure an accession of wealth. It was only those, however, who had patience to persevere in acquiring a knowledge of the machines, and who had diligence enough to attend to their careful construction and working, who succeeded in the race for riches.



SHEEP WASHING.

WOOL AND WORSTED.—VII.

A CLOTH FACTORY—GENERAL VIEW.

BY WILLIAM GIBSON.

WE can hardly realise that within the memory of some men still living the factory system was in its early infancy; and perhaps a few may recall the time when most of the processes through which wool goes in its transformation into cloth were carried on in separate buildings. But, strangely enough, the nineteenth century joins hands with the first; for shortly after the Roman invasion finally took effect, we find a cloth factory—certainly the earliest that existed in this country—established at Winchester, from which the soldiers of the various cohorts were chiefly supplied with raiment; and in course of time the inhabitants of the country were induced not only to adopt Roman manners, but the dress, speech, and religion of their conquerors. Hence we find Tacitus, in his Life of Agricola, saying, "*Inde etiam habitus nostri honor et frequens toga.*"* We can in fancy see the rough soldiers, doffing their arms, busily engaged in combing and weaving wool, while their wives spun it into threads; and the half-tamed Britons, looking on in wonder, by and by were induced to go within the factory walls as scholars, and their sweethearts, sisters, and wives were taught by Roman matrons the art of spinning. Up to that time they had no knowledge of woven cloths, for they wore the skins of animals with the fur still adhering to them. We know that this factory was a Government establishment, for the manager—called a procurator by Tacitus—was appointed by the Emperor. Here began the woollen industry of England, which has now reached such gigantic proportions, and in this way was inaugurated the factory system. History is silent as to the growth of the division of labour; but we know that it must have been the ever-increasing demand for textile fabrics which led men to confine their attention to specific departments of labour. At any rate, in course of time sorters were employed at their own homes; wool combers likewise worked at their own firesides; one family was occupied in fulling, another in milling, another in shearing, another in finishing. And in the wool-producing districts, every woman had from early youth been trained to spin; while in almost every house the father and sons set up a loom or two, and busied

* "Hence, too, a liking for our dress sprang up, and the toga became fashionable."

SOUTHDOWNS.

themselves all day throwing the rude shuttle to each other across the warp. That state of things continued till the present century, when the invention of machinery enabled manufacturers to congregate the various handicraftsmen under one roof, and we returned to the example which the Romans had set us in the first century. Of course, in all ages there have been individuals who carried on specific operations on a great scale, and these employed large numbers of operatives in a large house or factory; but weaving, combing, and spinning were, until very recently, carried on in individual households. The first man, so far as we can discover, who thought of congregating spinners into one place was John Whitcomb, a famous manufacturer in the time of Henry VIII. In a poem of his he describes his establishment. Beside the sorter's was the spinning room, or, as he graphically puts it—

> "And, in a chaumer close beside,
> Four hundred maidens did abyde,
> In petticoats of stammel red,
> And milk whyte kerchers on their hed."

Now, however, all that is changed: the fleeces of sheep come in at one end of a factory, and leave it at the other ready for the tailor. The wool comes to the manufacturer in small bales containing from two to five fleeces each. They are handed over to the sorters, who unerringly distinguish the quality of the wool from various parts of the sheep. The qualities of wool are ten in number, and are called picklocks, prime, choice, and super. These are the finer sorts, and are grown chiefly along and on each side of the spine. The coarser kinds are head-wool, downrights, seconds (from the throat and breast), abb (inferior to seconds, and from the same part of the sheep), livery (coarse, long belly wool), and short coarse, which grows on the breast. For all the finer descriptions of cloth, short wool is used, and the raw material is almost entirely imported from Saxony and Spain. For tweeds, medium length wool of home and colonial growth is used, the fleeces being obtained from the Southdown, Norfolk, Dorset, Cheviot, and Australian breeds. Long wool is used entirely for worsted materials, or mixtures of worsted and alpaca, worsted and silk, and worsted and mohair. The reason short wool is chosen for the finer sorts of cloth is that it is naturally softer, and its felting property is superior to long wool. The yield of the Leicester and Lincoln breeds, however, is sometimes broken into convenient lengths for the coarser kinds of tweeds, carpets, tapestry, &c. The finer sorts of Saxony and Spanish wool are from $\frac{1}{1400}$th to $\frac{1}{1500}$th part of an inch in diameter, and usually from $1\frac{1}{2}$ in. to 4 in. in length.

Although the fleece is well washed while on the sheep's back, nothing can be done with it until it is thoroughly purified, not only from the dirt which the river water did not take out, but the natural greasy substance by which it is impregnated, called "yelk." The scouring process is therefore the initial stage preparatory to other essential preparations. A long, narrow trough, partially filled with warm water and some strong alkaline, is used. At one end of it there is a feeding apparatus which carries the fleece into the trough. In the interior are four sets of hooks which move backwards and forwards, dragging the tufts of wool forcibly through the water. When sufficiently cleansed, it passes out

at the other end of the trough, is carried on to a pair of rollers, between which it is thoroughly squeezed, and then sent forward to the drying machine, where it is subjected to a hot-air blast till free from moisture. Notwithstanding all the labour so far bestowed upon it, the wool still retains a good deal of dust, and as it is more or less matted, requires to be torn clear. It is therefore next sent to the willy or willow—a machine whose name seems to be a corruption of winnow. The willy is a conical-shaped revolving drum, with sets of spikes round it, moving within a case with spikes set so as to go between those of the cylinder, allowing as small a portion of wool as possible to pass in a matted form. Torn to pieces in passing from the top of the machine to the bottom, it falls into a receiver, through which passes a strong blast of air produced by a mechanical fan, and so it is winnowed from all particles of dust. All that now remains is to free it from burrs, twigs, and other substances which got mixed with it while it was the covering of a sheep. In order to remove these, it undergoes the process of burring. An ingenious machine for doing this work—the invention of a Belgian mechanician named M. Martin—is in general use, and it is capable of cleaning 300 lb. of wool per hour. The wool is now white and clean, and if it be destined for superior cloth, it is handed over to the dyer, or if for the coarser and commoner sorts, that operation is left to a future stage.

Meantime, the wool is too dry and brittle to be manipulated conveniently, and hence it has to be well oiled. Formerly, this was done by spreading it out in a thin layer on a floor and pouring some vegetable oil over it, which was subsequently thoroughly rubbed in till every hair had its proper share. Now, however, this process is far more quickly and efficiently done by a machine patented by Mr. George Leach, of Leeds. This "oiler" keeps the wool in motion while a great number of fine jets cast a spray of oil over it. If the cloth intended to be made is to be of several colours, the shades are now mixed, and the material is ready for the "scribbler."

Scribbling is a preparatory carding, two main results being aimed at—thoroughly to separate the fibres, and to throw them over one another in as many different directions as possible, so as to facilitate felting. The scribbler consists of a main cylinder, over which is drawn a belt of leather, india-rubber, or other suitable material, closely studded with fine steel spikes slightly bent at the points, and round it, revolving in various directions, are a number of smaller cylinders, similarly armed. The machine is fed by an endless apron, and the wool, as it passes between the innumerable teeth, gets separated into filaments, which are tossed about and mixed in inexplicable confusion. By this process the wool is rendered lighter, evener, and more homogeneous. Having passed several times through this machine, the material goes to the "carder," which is very similar in construction. The chief distinction is that the teeth or spikes on the cylinders are finer and more closely set. When thoroughly carded, the wool is taken off by a "doffer" in a thin strip or "sliver," about 32 inches

Leicester Sheep.

in length. Attached to the most modern carders is what is called a "piecer"—*i.e.*, an appliance for joining the "cardings" in a continuous thread. The "carding" passes over leather bands, through a ring or groove, and between rollers which give it a slightly yarn-like shape. This tool is called a "condenser," because it reduces the bulk of the "sliver," and generally delivers 74 perfect "slubbings," as the embryo yarn is now called, at a time. These are divided into three sets of 24 each, the two exterior ones generally being rejected as needing further "condensing." So perfect have carders been made that each machine is capable of turning out 56,000 to 60,000 yards an hour, and so fine that one ounce of wool is stretched into a thread over 350 yards in length. The slubbing machine is popularly termed a "billy."

Here a selection is made from the "slubbings," a portion being set apart to be made into warp yarn, and another for weft yarn. The warp yarn is not "spun" so hard as weft. However, both are now sent to the "mule," or spinning machine, which is almost identical with the spinning-jenny used in cotton factories. Some of the machines operate upon as many as 200 threads at a time, or, in other words, are capable of doing much more efficiently and evenly what 2,000 hand spinners could have accomplished in days gone by. Warp yarn is drawn directly off the mule cobs, sized, and warped in required lengths. The size used is a glutinous substance procured from rabbit skins, and besides giving the yarn a smooth surface which facilitates its being woven, strengthens it enough to admit of its being dealt with in the loom without breaking. All the weaving now is done on power looms, which only differ from those used in other branches of textile fabrication in their width of beam. Cloth has to be woven twice the width it is intended eventually to measure. Broadcloth measuring six quarters from selvage to selvage is woven three yards wide, and proportionately for narrow cloth. When the cloth leaves the loom, it is very different in appearance to a roll seen in a tailor's shop. It looks more like a blanket than anything else, and, held up between the eye and the light, is found to be full of interstices. Great care has to be taken in the weaving to get an even cast of the weft, and exactly the same number of "picks" to each inch of cloth. Unless this is attended to, the piece wrinkles and puckers in fulling. When it leaves the loom, cloth is technically known as "roughers."

Before anything can be done with "roughers," it requires to be freed from the oil and size with which it is impregnated, and hence it receives a second scouring with warm soapsuds. The scouring trough has a convex bottom, and is fitted with wooden mallets so arranged that they fall upon the cloth in an oblique direction, and, while beating it about to free it from oil and size, these mallets, or "hanging stocks," as they are called, prepare it for the next important operation. As soon as it is thoroughly scoured, it is hung up, either in the open air or in a hot-air chamber, till thoroughly dry, and then sent to the "burling" room. Burling or knotting is simply darning. While in the scouring trough, it may have been torn in several places, or in weaving there may have been imperfect spots in the weft. All these defects have now to be made good. Burling is done entirely by females, and is an important process. It might be thought that these darns would spoil the cloth, but it is not so; for after the web has passed through the fulling mill, no traces of the operation can be detected. Each web is now very closely examined by skilled operatives, and, if it has not been dyed before, is coloured now.

"Fulling" is the next step. The fulling, like the scouring trough, is filled with thick, warm soapsuds, and, like it, has a number of wooden mallets arranged so as to beat the cloth when thoroughly saturated with the warm soapy water. But instead of falling upon the material obliquely, they strike it at right angles. Some manufacturers, instead of using "fulling stocks," or "hanging stocks"—the old method long held to be the only efficient one—subject the woven material to great pressure, which answers the same purpose; but the best materials are always beaten till the warp and woof are "milled," or rendered like a piece of felt. Everybody knows that knitted stockings shrink very much in washing, and the longer they are allowed to remain in hot soapy water, the more easily the threads "felt." Careful housewives, therefore, in washing woollen stockings, should use water barely warm, as little soap as possible, and take care not to allow them to remain too long in the "suds." Stockings should also be wrung very lightly, and subjected to the least amount of friction, or in a short time they will be unfit for wear. The felting property of wool is its most valuable one, and will be explained fully hereafter. Suffice it to say now, that a filament of wool is covered with scales like the skin of a fish, and that when placed in hot soapy water, these scales rise at right angles almost from the thread; and when force or pressure of

any kind is applied, the warp and woof creep together, and the scales grip each other just as the dovetailing of wood. The more a piece of woollen cloth is beaten, the more it felts, till at last it assumes the appearance of a solid piece in which individual threads are very difficult to be distinguished. Fulling—or "milling," as it is sometimes called—is rather a tedious process. Single milling takes from 12 to 20 hours, double milling from 24 to 40 hours, and treble milling as long as 60 hours. Ordinary cloths, tweeds, &c., are single milled, the better kinds of material double milled, and the finest broadcloth treble milled—*i.e.*, passed once, twice, or thrice through the fulling mill. The beating or pressing is not exactly continuous. After being hammered, or pressed between rollers, which answers the same purpose, for an hour or two, a stream of cold, clear water is allowed to run over the web till it is free from soap; then it is put back and re-beaten in the fulling machine, again taken out and rinsed, put back to punishment, and so on, till the process is completed. Before being milled, a piece of broadcloth is generally 3 yards wide and 63 yards in length. When single milled, it will be found to have shrunk to half its former width, and now measures not more than 40 yards in length; and if double milled, or treble milled, the shrinking process still goes on, though not to the same extent.

Once "milled," the cloth is taken to the tenter frame, which is simply composed of two long pieces of pine wood, or some substitute—such as an iron frame—kept equidistant from end to end, with iron spikes, or tenter hooks, driven into the parallel pieces of wood at equal distances. The cloth is hooked on to these spikes, so as to be tightly stretched, and allowed to dry without wrinkling. Were it not so "tentered," some portions might felt more than others, according as the yarn had been more or less twisted; but by being stretched like canvas on a frame, it dries evenly, and when taken off is of a uniform width throughout. The next operation is one of the most important in the whole process. It is called "teaseling." When the cloth leaves the fulling mill, the surface has a hairy appearance, caused by the ends of the wool protruding from the yarn. These loose filaments have to be further torn out, so as to form the "nap," and for this purpose the cloth is, so to speak, curry-combed. The "teasel" is the ripe fruit of a cone-bearing plant, known to botanists by the name *Dipsacus fullorum*. The fruit is a conical burr, with hooked points bristling all over it, something like the prickles on the common thistle. These hooked points are all curved in the same direction, from base to apex of the cone, which is usually about 2 inches long. The points are strong, highly polished, partially elastic, and exactly fitted to tease out the threads from the surface of woollen materials. Endeavours have been made to imitate this natural product, but hitherto without success, and the teasels in use now are very similar to those that have always been associated with the manufacture of woollen cloth. The teasel is split, and fastened on frames or cylinders, so as to present a uniform prickly surface. Over these "spines" the piece of cloth is drawn, till all the loose ends of thread have been torn out, and the material looks like the shaggy coat of a wild pony. Thistles were used till the peculiarities of the *Dipsacus* were discovered, and now that plant is grown with the greatest care, so as to get the most perfect burrs. Some makers, before teaseling the cloth, subject it to what is called "hand raising." This is done with stiff metallic brushes, so as to induce the "nap" to come out, and present a rougher surface to the teasel.

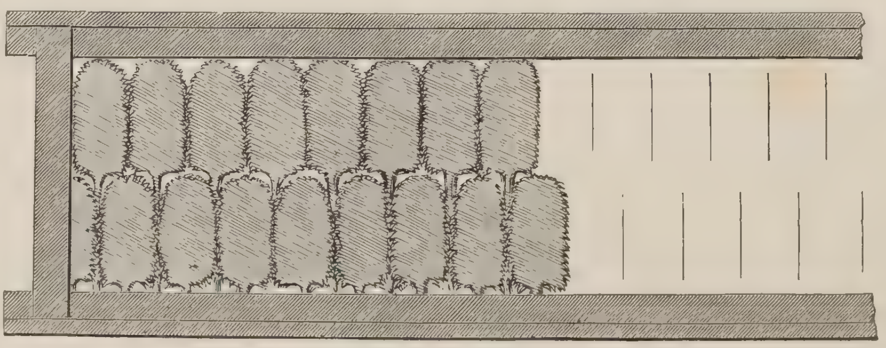
Shearing, cropping, or shaving is the next process. When the cloth leaves the teasel, the nap is uneven—some threads long and others short; and the shearing is the means by which it is reduced to a level velvety pile. Formerly, this was a very tedious and difficult operation, and a good "cropper" was in great request; but as it is now accomplished by mechanical aid, the work is more quickly and much better done. The knives used are flat steel discs, with keen edges, which work against a thin circular bar of the same metal, called a "ledger blade." The shearing apparatus will be fully explained in its proper place, but it will give the reader a good idea of the character of the tool to watch a good lawn-mower at work. In that implement the revolving cylinder is fitted with pieces of steel set diagonally on the exterior surface of the cylinder, their edges standing out. The cylinder being made to revolve rapidly, the tops of the blades of grass are cropped off evenly as the mower is pushed along. The cloth mower acts on the same principle, but, instead of being a cylinder, is like a wheel, the steel knives being set round the "tire," to keep up the metaphor—or "ledger blade," to speak technically. The wheel is wider across than the cloth, and, as it rapidly revolves, the knives or steel discs spin round, and are pressed against the tire, thus shaving or mowing the end of the nap that is raised by a mechanical brush. This is done

so evenly that there are no shear marks left, as on a lawn that has just been mowed. The machine is called a "dresser," and has been perfected to such a pitch that it razes the nap close to the body of the cloth, uniformly over the whole web, and with such rapidity and certainty, as to be simply marvellous, yet without injuring the body of the material.

TEASEL.

Having undergone all these operations, the cloth begins to assume the appearance with which we are all familiar, but the more costly fabrics are not yet ready for the market. The final process is called "lustering" or "decatting," and this is elaborate or simple, according to the quality of the article. For meltons and pattern cloths, the process is comparatively simple, as for all materials to which a high finish is not necessary. The generally approved process is to wind the web tightly over an iron cylinder, care being taken that no wrinkles are made during manipulation. A vat filled with hot water, which is kept at an equable temperature of 160° to 180° Fahr., is ready, and the cloth and cylinder are allowed to steep there for six or eight hours, when they are taken out, dried on steam rollers, and calendered. By this means the cloth is thoroughly shrunk, and the surface made to wear that uniform lustrous appearance which prevents it becoming "patchy" when it assumes the form of a garment. In some factories, instead of being soaked in water, the web is placed in a steaming box, and subjected to the action of vapour. The effect in either case is very similar, but some prefer this plan on account of its rapidity; others question whether it is so satisfactory as the older method. The superfine cloths go through a more elaborate operation. After being steamed or soaked, the web is taken out and dried, after which the nap is raised by a steam brush, and it is cropped with a Lewis or other cutting machine. It is again wetted, raised, and cropped, and steam pressed, or put through a calender. This is repeated three, four, or five times, according to the degree of finish desired; and in some cases even as many as eight or ten times. After being carefully examined, burled, and drawn the second time, for any little defects, it is finally pressed between hot plates, rolled, and packed for delivery to the consumer.

Worsted cloths are treated very differently; but the various processes employed in this branch will be explained in a future chapter. Our endeavour has been to give the reader a general view of the various operations carried on in a cloth factory, and to indicate in a rough way the character of the machinery employed. The more important classes of fine cloth are as follows:—West of England Broadcloth; Doeskins; Cassimeres or Kerseymeres, which only differ from the former in lightness of body, having four threads instead of seven in warp and weft; Sataras, the generic title of all ribbed materials; Venetians, the name applied to all twilled fabrics; Meltons, which are pared, but not close cut as doeskins, and appear much the same on both sides; Beavers, a kind of material in which the nap is longer, being only pared and milled; Deerskins, much like Venetians, but still lighter in weight, and woven with a weft of equal strength to the warp; Diagonals, a name applied to all striped or lozenge-shaped patterns woven in the body of the material; Bedford cord, a stout leathery material of which our grandfathers had their breeches made; and Tweeds, which are woven of medium wool, slightly felted, and only pressed and dressed. Really belonging to this class of fabrics are the Irish Friezes, of which the best ulsters are made, and those materials which



TEASELS IN THE FRAME.

are partly felted from mixed materials; but the latter class of goods will find its proper place under the head "shoddy." Hampshire, Wiltshire, Gloucestershire, Kent, and Yorkshire are celebrated for their fine cloths; Cumberland, Norwich, and the South of Scotland for the lighter materials; and Scotland especially for tweeds; but in the district round Leeds almost all classes of goods are now manufactured, and here the machinery and appliances have grown to greatest perfection.

IRON AND STEEL.—VIII.

THE BESSEMER PROCESS.

By William Dundas Scott-Moncrieff, C.E.*

IN the methods employed for producing steel now universally known as the Bessemer process, we come upon a new era in the history of the iron trade. These discoveries, although based on principles well known to scientific men, were on their first announcement held to be wholly incredible by practical iron manufacturers, who were acquainted with malleable iron *only as a solid substance*, which the highest heat of their most powerful furnaces merely sufficed to render sufficiently soft to yield to the blows of the hammer; hence the proposal to convert molten pig iron into fluid malleable iron, in a few minutes, and without the consumption of additional fuel, was considered an absolutely impossible feat. It is to the genius and unwearied perseverance of Mr. Bessemer that we owe the combinations of chemistry and mechanics which, long after they had overcome the obstacles of nature, obtained a slower and more difficult victory over the prejudices of habit and ignorance. He was indebted to no one for his facts—they were the common property of every practical iron-master; his conclusions were verified by his own experiments. He has been accused of not acknowledging assistance with sufficient generosity; but when a man is placed on the defensive against the assaults of a wealthy trade and a flood of would-be inventors, each one struggling to gain a secure foot-hold on his invention by securing to themselves the exclusive right to some trifling but obviously necessary detail, he is surely the best judge as to whether he should hail such officious friends as real helps, or merely selfish obstructors.† No one can say that, if Mr. Bessemer had succumbed to the difficulties which surrounded him, any other man was sure of success. It is this position which entitles him to rank among great inventors.

In order to enable the reader to understand the *rationale* of the process, we cannot do better than refer to what was known previous to the discoveries of Mr. Bessemer, and then show how he took advantage of that knowledge. Previous to his discoveries being made public, many of the facts which he made the foundation of his invention were thought of no importance. If a nail is tied to a cord, and the point heated to whiteness, it can be made to burn in common air by being whirled round in a circle. A ring of sparks is formed, which proves that combustion is proceeding. In the manufacture of horse-shoe nails this process is carried on by means of a small pair of bellows, which force a jet of air upon the white-hot bar of iron that is being hammered on the anvil. Mr. Bessemer was the first to show that if air was forced, not upon the surface merely, but into and amongst the particles of molten iron, the same sort of combustion took place; and the heat obtained in this way is more intense than any that had been used previously, either in the blast furnace or the process of puddling. A paper was communicated to the Royal Irish Academy in 1862, by which it was attempted to prove that the Japanese adopted a similar method for the fusion of iron 300 years ago; but there was nothing in the description of Mandelslo, whose narrative was quoted, to show that the two were by any means identical. This attempt to disparage Mr. Bessemer's invention shows how far jealousy will go afield when the object is detraction.

We must now ask the reader to go back to the earlier chapters upon the blast furnace and the manufacture of malleable iron, in order to understand the connection between this application of air to molten iron and the process of decarburisation

* My thanks are due to Mr. Bessemer for his kindness in revising this paper.

† The stories of Henry Cort and of Heath are a sufficient warning against the ingenuous acknowledgments of inventors.

which it brings about. It was there explained that when all impurities have been removed from iron, the only condition which is known to regulate its character is the admixture of carbon in different degrees and under different forms. Highly carbonised iron comes from the blast furnace as a fluid, and is at once formed into pigs, which are used for the foundry, and for conversion, as already described, in the puddling furnace. The malleable iron which is obtained from this process is simply purified pig iron with the carbon removed, and this again is capable of being converted into various kinds of steel by being melted in crucibles and carbon added to it under different conditions. It was also explained that the chemistry of decarburisation consisted in the practice of exposing the highly-heated metal to the action of the air, when the carbon combines with the oxygen, for which it has a greater affinity than the iron. There are other combinations which take place in the puddling furnace between the oxides of iron and the carbon at high temperatures, but the principal agent for the removal of the carbon is the action of the oxygen obtained from the atmosphere. But in this, as in all previous processes, this decarburisation, by rendering the metal less fusible, results in a solidified mass, in which much scoriæ and other mechanically mixed impurities are combined. It is not quite clear from Mr. Bessemer's patents when the far-seeing deduction of combining the use of common air, in the double purpose of increasing the temperature and removing the carbon at one operation, occurred to him. This is doubtless owing to the fact that a patentee frequently finds it necessary to secure his invention step by step to prevent important facts from becoming known, and thus entrench himself on all sides against assault, by suggesting possible combinations which, if not the best suited for his purpose, would, if in possession of his rivals, be used against him. Thus the use of steam combined with air in the decarburising process, was patented by Mr. Bessemer with a full knowledge on his part that the use of steam by its decomposition tended to cool the metal, but the hydrogen thus set free always lessened the quantity of sulphur present in the metal, and being a useful combination might, if unclaimed by him, have left open a door through which his invention might have been invaded. A further patent of Mr. Bessemer's, obtained in 1856, makes it clear that he had arrived at a sound notion of the true theory; for there he speaks of effecting the conversion of the pig iron "by forcing into and among the particles of a mass of molten iron currents of air or *gaseous* matter containing, or capable of evolving, sufficient oxygen to keep up the combustion of the carbon contained in the iron till the conversion is accomplished." Here we have a clear exposition of the idea of removing the carbon from the iron by the act of burning it with oxygen at a high temperature. In this patent, reference is made to the appliances specified in the previous patents, and taken in combination, there is a complete embodiment of the essential elements of Mr. Bessemer's invention. It is one thing, however, to reach a point in practical investigations of this sort, when it is satisfactorily proved from experiment that certain things can be done, but a much more arduous task to carry out the practice of the discovery in competition with existing methods of production. In the puddling furnace there are opportunities for manipulating the iron, and mixing it with silica, oxides of iron, and other ingredients, which are not possible in a great crucible containing a mass of molten iron such as is used in the Bessemer process. Even when the inventor had overcome the great practical difficulties in arranging the mechanism of his receiver so that it could be handled with precision, and the air turned on without the passages being choked by the pressure of the superincumbent mass, there remained much to be done, for it was found impossible to produce either malleable iron or steel of good quality from the inferior kinds of pig iron, and which fact led the great majority of iron-masters, and even scientific metallurgists, to predict that it would never take an important place among the great inventions of the iron trade. It was also predicted that if the products of the process were of a superior quality, the price at which they could be produced would always remain excessive. The reader may gather from all this how much unwearied patience and perseverance were required on the part of Mr. Bessemer and his partner, Mr. Longsdon, to bring the invention to its present perfection. Inventors, like travellers in unknown regions, have to ascend with infinite fatigue the most arduous acclivities, and when most in the belief that the summit is attained, have often to make still harder efforts to surmount intervening obstructions.

This has been particularly the case in the various stages of Mr. Bessemer's invention, because the difficulties that presented themselves could not have been predicted, and must have appeared as unexpectedly as a fresh rising ground that has been

hidden from a traveller by an intervening hill. No sooner was the apparatus brought to sufficient perfection to enable the workmen to remove the carbon, than they found that they had no means of knowing when it was time to stop the process, except by the appearance of the sparks and flame issuing from the vessel, and these indications were not sufficiently marked in all cases to enable the amount of decarburisation to be ascertained with perfect accuracy. Mr. Bessemer then resorted to the expedient of measuring by a suitable indicator the number of cubic feet of air passed through the metal, by which means the amount of decarburisation could be judged of with tolerable accuracy. In his patent of October, 1855, another method of regulating the temper of the metal is described in these words:—"The state of the metal may be tested by dipping out a sample with a small ladle, as practised in refining copper. If too much carbon is retained, the blast may be continued for a short time, or a small quantity of scrap iron may be put into it; but if too much carbon has been driven off, an addition may be made of some melted iron from the finery or cupola furnace."

This mode of recarburising by the addition of molten pig iron was most effective, and was immediately followed by the very obvious practice of entirely decarburising the metal, and then adding a known weight of melted pig iron, and thus producing steel of any desired temper with the utmost certainty. Some months later, Mr. Mushet, who is well known as a worker in the fields of metallurgical discovery, obtained a patent for the recarburisation of the converted metal by the employment of that particular kind of pig iron known as spiegeleisen. Mr. Mushet could not, however, maintain his patent against Mr. Bessemer's prior claim to use pig iron generally. For this purpose spiegeleisen has the advantage of containing much manganese, a substance which, since the discovery of its use by Heath, some forty years ago, has been regarded as a necessary element in the production of the more malleable descriptions of cast steel. It was in this manner, and no doubt after many fruitless experiments, that a certainty as to the proper amount of carbon was obtained. There were still many obstacles in the way of successfully competing with the productions of existing methods, and although the material that was produced by the Bessemer process was superior to common malleable iron for many purposes, the price at which it could be sold was still too high to admit of its general adoption. One of the greatest difficulties presented itself in the presence of phosphorus, which is sometimes an unobjectionable element in castings, but renders all kinds of steel and malleable iron so brittle as to be unfit to withstand the strains of tension that occur in almost every practical purpose to which they are applied. It appears that the process of puddling is more capable of eliminating phosphorus and sulphur than any direct process for removing carbon by the action of oxygen, and that the Bessemer process is at a disadvantage in this respect. But it had already become apparent that the theory of the new method was too well established to admit of its being abandoned on account of the accident of foreign substances which were found in the argillaceous or clay ores that had been hitherto chiefly used in the blast furnaces of this country. A passage occurs in one of the ablest books that have ever been written on the subject of the mineralogy of iron and steel, Dr. Percy's, which is so apposite that we cannot do better than quote it. There is nothing that affords greater delight to minds intent upon scientific investigation than the clear and honest exposition of problems which remain unsolved. In dealing strictly with the definite condition of knowledge at the time to which a writer refers, there is the advantage of being correct even when the facts are on the eve of new combinations which materially affect the result. There is no writer who has more rigidly adhered to scientific exactness than Dr. Percy; and where he sometimes appears to be wanting in hopefulness, it is only because he sees no clear way out of the difficulties that existed at the time he was writing. In a paper read before the Institution of Civil Engineers, by Mr. Bessemer, in 1859, which has now become of historical interest in the records of the iron trade, the writer spoke as follows:—"Why should it be attempted to stick dirty little granules of iron together, and then to squeeze the impure mass, until it is so small as to be useless, until it is again fagoted up and imperfectly united, and thus for ever to multiply the defects which its first treatment entails?"

This question refers to the process of puddling, and Dr. Percy replies to it as follows, writing in 1864:—"There is a ready and sufficient answer—viz., at present no alternative is known. Bessemer's process is powerless to convert ordinary kinds of pig iron into merchant iron of the least value; whereas, this is every day accomplished by the old and barbarous method of puddling. With the exception of certain varieties of red hæmatite, all our iron ores contain a sensible amount of phosphoric acid, of

which, practically, the whole of the phosphorus passes into the pig iron smelted from them. The proportion, however, raised of the former is small in comparison with that raised of the latter; but it is only with pig iron practically free from phosphorus, that Bessemer can deal satisfactorily, and such pig iron forms merely a fraction of the total produced in this country. It will be time enough for Mr. Bessemer to sneer at puddling when he can show how that laborious operation may be dispensed with. He has not yet done so." We cannot help regretting that such an eminent authority as Dr. Percy should have joined so far with those whose position has since proved to be wrong, because an element of sanguine sympathy might have been expected from him towards a system that had advanced so far in the direction of sound theory and practical experiment. Yet, what Dr. Percy then said was quite true. He made no rash predictions, and came to no unscientific conclusions. He was correct in stating that "Bessemer's process is powerless to convert ordinary kinds of pig iron into merchant iron of the least value," but the red hæmatite ores, which were then a fraction of what were raised in this country, have become of paramount importance. Dr. Percy failed to see in the new process an element of commercial power that attracted capital and changed the relative values of the mineral wealth of this and all other civilised countries. When it was discovered that only those ores were available for the Bessemer process which were free from phosphorus, the spirit of inquiry was abroad. Vast fields of ore were opened in Cumberland and Lancashire that had been previously neglected. Blast furnaces were erected for producing the pig iron best suited for conversion under the new system. Trade sprang up with other countries that contained the ores that had so suddenly become enhanced in value. Steam ships were built of the dimensions best suited for conveying it. Towns were built in the centres of the new industry, with a rapidity only equalled by the mushroom creations of the western prairies of America. Capital flowed towards the fresh and tempting outlet for its profitable employment; fortunes were made, and within a few years this department of the iron trade had risen to a position of national importance. It is hardly necessary to add that Mr. Bessemer's position as a great inventor has been confirmed.

In describing the process, we cannot do better than return to the papers read by Mr. Bessemer before the British Association and the Institution of Civil Engineers. The first of these was read at Cheltenham, in 1856, and as it was the first publication of his invention in that form, excited an immense amount of interest. It was entitled "On the Manufacture of Iron and Steel without Fuel." Dr. Percy takes exception to this title, because, as he rightly observes, fuel was necessary both for the smelting of the ores, for the production of the pig iron, and also for the melting of the metal previous to its being conveyed into the converting vessel. He then describes his first impressions on seeing the process in operation. From its interest as a contemporary record, we make no apology for giving it at length:—"Towards the end of 1856, I had the pleasure of seeing the process in operation, at Baxter House, where Mr. Bessemer then resided, and I confess I never witnessed any metallurgical process more startling or impressive. After the blast was turned on, all proceeded quietly for a time, when a volcano-like eruption of flame and sparks suddenly occurred, and bright red-hot scoriæ or cinders were forcibly ejected, which would have inflicted serious injury on any unhappy bystanders whom they might perchance have struck. After a few minutes all was again tranquil, and the molten malleable iron was tapped off. At first I doubted whether the metal which I saw flowing, was actually malleable iron; and after the analysis in my laboratory of a portion of this identical iron, and the detection in it of somewhat exceeding 1 per cent. of phosphorus, my scepticism was rather confirmed than otherwise. However, I soon became convinced that Mr. Bessemer was correct in asserting that he had succeeded by his process in producing a temperature higher than ever 'before attained in metallurgical operations'—sufficient, indeed, to render malleable iron as liquid as water. The mass of metal in this case is not heated, as usual, from without, under comparatively unfavourable conditions, but active combustion takes place everywhere in the mass itself, under conditions the most favourable possible for the development of high temperatures. Mr. Bessemer was not the first to discover the fact that iron, when heated to a certain degree—say bright redness—might be raised to a much higher temperature by exposure to a blast of cold air, the additional heat resulting from the rapid oxidation of the metal. We have seen that the nailers in some localities use a blast expressly with this object. Now, if solid iron could be thus heated, the same result might reasonably have been predicted with respect to molten pig iron; but I am not aware that it ever was, or if it had been,

it was never applied." This description will convey to the mind of the reader some idea of the manner in which the chemistry of the Bessemer process is carried on. In an ordinary fire, such as that which is used for warming our houses, in grates or stoves, the temperature is so low compared with the heat of molten iron, that the burning of the carbon—which goes on by the passage of the air with its oxygen over the red-hot coals—is as nothing compared to the somewhat similar process of combustion in the Bessemer converting vessel, but the analogy is so close that it forms an illustration. Just as the coal is consumed in the one case with a great disengagement of heat, so the carbon disappears under similar conditions of combustion in the other. When it is explained that the vessels containing the iron which is raised to this excessive temperature are made of iron, and require to be moved about with precision, it will be understood how many expedients must be adopted to prevent them from being warped or destroyed. This is done by covering the interior with a thick lining of unmeltable materials, such as those employed in the ladles used for conveying melted iron in foundries. The converting vessels are shaped in such a way that when they are swung into a horizontal position upon trunnions, like a cannon, the mouth projects upwards at an angle of about 45°, so that the molten pig iron can be poured into them. At the same time, as long as the "converter" is in this position, the bottom, which is perforated with holes for the admission of the blast, is uncovered by the molten contents. As soon as the blast is turned on, however, the vessel is tilted into a perpendicular position, and then the air goes through the seething iron. In Mr. Bessemer's own words, the process is then "brought into full activity, and small though powerful jets of air spring upward through the fluid mass. The air, expanding in volume, divides itself into globules, or bursts violently upwards, carrying with it some hundred-weight of fluid metal, which again falls into the boiling mass below. Every part of the apparatus trembles under the violent agitation thus produced; a roaring flame rushes from the mouth of the vessel; and as the process advances it changes its violet colour to orange, and finally to a voluminous, pure-white flame. The sparks, which at first were large, like those of ordinary foundry iron, change to small hissing points, and these gradually give way to specks of soft bluish light, as the state of malleable iron is approached." The blowing goes on for a period varying from ten to twenty minutes, according to the nature of the pig iron which is being converted, and when the carbon has been sufficiently removed by its combustion with the blast of air, the vessel is again turned upon its side to receive the charge of molten spiegeleisen already referred to. It is then turned to a perpendicular position, and the blast renewed so as to thoroughly incorporate the mixture, and then it is poured, first into a large ladle, and from that again into moulds, where it cools into the ingots, which are hammered and rolled in the same manner as the "blooms" of the puddling furnace. (*See* FRONTISPIECE.)

In conclusion, it may be stated that by means of the Bessemer process the cost of tough homogeneous cast steel has been so greatly reduced as to economically admit of its use for all constructive purposes. As an example of its reduced cost, it may be stated that prior to Mr. Bessemer's invention we have no record of a bar of cast steel of any form (weighing as much as an ordinary railway bar) having been sold at so low a cost as £40 per ton, while at the present time many thousand tons have been sold at or below £6 per ton. The whole quantity of steel manufactured in England immediately prior to the introduction of the Bessemer process did not exceed 51,000 tons annually, while of Bessemer steel alone no less than 750,600 tons were made in the year 1877 in England alone, of which 234,000 tons were exported in the form of rails, having a declared value of £1,926,714. During the year 1877 there were also manufactured in the United States 525,996 tons; in Germany, 242,261 tons; in Belgium, 71,758 tons; in Sweden, 21,789 tons; and in France, 261,874 tons, making a total in these six countries of 1,874,278 tons, which in the various forms of rails, tyres, cranks, plates, bars, rods, &c., may be fairly estimated at a net value of no less a sum than £20,000,000 sterling.

FOREIGN RIVALRIES.—IV.

TOOL MAKING AND TOOL USING.

By H. R. Fox Bourne.

"MAN is a tool-using animal. Weak in himself, and of small stature, he stands on a basis, at most for the flattest-soled, of some half square foot, insecurely enough; has to straddle out his legs, lest the very wind supplant him. Feeblest of bipeds! Three quintals are a crushing load for him; the steer of the meadow tosses him aloft, like a waste rag. Nevertheless, he can use tools, can devise tools. With these the granite mountain melts into light dust before him; he kneads glowing iron as if it were soft paste; seas are his smooth highway, winds and fire his unwearying steeds. Nowhere do you find him without tools; without tools, he is nothing; with tools, he is all." So says Herr Teufelsdröckh, Mr. Carlyle's spokesman in "Sartor Resartus," and the words, which might serve as text for an essay on the whole history of civilisation, aptly indicate the supreme importance to individuals and nations alike, in their competition with one another, of skill in the making and using of tools. The term may fairly be employed, if in a narrower sense than Mr. Carlyle's, in one broad enough to include all instruments designed for the manufacture and perfecting of all sorts of commodities which men find it convenient to have for their use or enjoyment. If articles with which still, as in times gone by, the carpenter converts a plank of wood into a box, or the gardener digs the soil, or the seamstress fashions a dress, are tools, so also are the great sawing mills and steam hammers, the huge ploughs and reaping machines, the complicated apparatus by which cotton, woollen and other textile fabrics are spun and woven and prepared for the market, and the steam engines and similar agencies whereby these and a thousand other operations are performed in modern times. "What I sell here, sir," old Matthew Boulton said to Boswell when he was showing him over his establishment at Soho, "is power." It is to this stupendous addition of the power gained by mechanical appliances to the best that mere hand labour can do, that the great revolution in the material condition of society, which has taken place during the past few generations, must be in a large measure attributed; and the success of our own country herein is a main cause of its industrial supremacy over so many other nations. Reserving for future papers such details as it may be well to give concerning English enterprise and the foreign rivalry with which it is met in special trades, we may in this chapter take some account of the more general aspects of the question.

Modern tools or manufacturing appliances being so largely composed of metal, and especially of iron or steel, the advantages possessed by England in this respect, to which reference has already been made, have naturally contributed to its eminence as a tool-producing nation. The persons who put to good use the physical resources of the country, however, must not be forgotten; and, if we have reason to remember our men of genius with pride and gratitude, the honour due from us to those other men—hardly to be credited with the special endowment of genius—who leagued with them in elaborating and reducing to practical shape their brilliant conceptions, is certainly not less. It may have been little more than a fortunate accident that James Watt, the inventor of the steam engine, came from Glasgow; it was something more than an accident that he found in Matthew Boulton, of Birmingham, a colleague able to develop the invention into the greatest mechanical boon that has ever been given to the world. Other men, foreigners as well as countrymen of Watt's, had very nearly anticipated his scientific triumph. He himself, like Columbus with the New World in his brain, might have wandered from country to country, vainly seeking an opportunity of turning his well-grounded fancy into a reality, had not Boulton been willing to risk everything in the service of his friend, of himself, and of mankind. Though England has been blessed with many of them, men of genius like Watt are of no special nationality. Meteors rather than suns, they are of small avail unless the light they are prepared to give can be caught hold of, so to say, and made use of. It is in being able to produce such practical men as Boulton—intelligent enough to apprehend the teaching of the men of genius, and patient and energetic enough to give it due effect—that England is particularly favoured; and there was a goodly number of them in our country a century or so ago. They saw what uses could be made of the scientific discoveries and improvements offered to them. They saw also what uses could be made, by application of the new inventions, of the raw

material lying idle around them, or half-hidden underground; and they knew how to utilise the capacities of the labouring population in their midst. Wedgwood and others in Boulton's own day, Peel and others a little later, were of that stamp. By their shrewdness and enterprise, England has been immeasurably enriched; and if it cannot hope always to enjoy the supremacy they helped it to win as a tool-making nation, its people may console themselves by reflecting that what is loss to them is gain to the inhabitants of other lands.

Our country, of course, would not have produced so many great manufacturers—"iron kings," according to the term applied by Boswell to Boulton—had not the material out of which such men are made been common among its working people. That it should still be so is a national advantage worth noting. It is often complained that English workmen are more difficult to deal with than foreigners; that in insisting upon more favourable conditions for themselves than Germans, Frenchmen, or Belgians are content with, they render their work almost too costly to be profitable; and moreover that their independence of character, their stubbornness, and even their foolhardiness, seriously interfere with their value as agents of men competent to direct them. There is some truth in such complaints; but the industrial greatness of England is not a little due to the tendencies that are apt to grow into these faults. An English workman refuses to be a slave. Before his apprenticeship is over, he has probably resolved that, if he can, he will be a master in time. Of course, only a few out of the multitude can realise this ambition; but those who succeed form the majority of our employers of labour; and those who fail still, by their earnest and honest desire to improve their condition, give a dignity to labour which it would not otherwise possess. Foreign nations send us plenty of merchants, financiers, and the like—families as famous as the Rothschilds, the Barings, and the Goldsmids; but it is very rare for them to supply us with such a prince among manufacturers as Henry Bolckow, the founder of the Cleveland iron trade, who died in June, 1878. On the other hand, it is to the enterprise of Englishmen and Scotsmen that a very large number of the great concerns on the Continent owe their origin. The example set by the Cockerills in starting the first iron works at Liége has been imitated, more or less successfully, times without number. Recently, and especially in such newly-opened manufacturing districts as those of Austria and Italy, this fashion has been modified by the formation of what are really branches of English establishments—English capital, English management, and sometimes English labour, being employed in working up, under more favourable conditions than exist at home, the tools and machines required abroad.

With the improvements that are being continually effected in modes of transport, both by land and by sea, it must be expected that England will lose more and more of the advantages it formerly had over foreign countries in tool making and tool selling. It is still found convenient that the great manufacturing establishments should be placed as near as possible to the coal and iron mines whose produce is chiefly used in their operations; and, as increasing competition renders it necessary that every sort of economy should be practised, this arrangement will doubtless be generally maintained; but it is by no means so essential as it once was, and in some respects circumstances are favouring a complete change in the method of procedure. In many cases, the materials of which the tools are made, and those which they are to help in manufacturing, are widely apart; and England has hitherto profited immensely by the fact that, being well supplied with the former, it has had the latter brought to it in large quantities. Of this, cotton furnishes a notable illustration. From the United States a far larger supply of the fibre is now obtained than from all the rest of the world put together. The United States is also as rich as Great Britain in the minerals necessary to cotton manufacture. Until lately, however, nearly all the cotton produced in America has been sent to this country in order to be wrought into clothing, the wants of even the Americans themselves being chiefly met by the re-transmission of their own cotton in a manufactured state. This arrangement was manifestly advantageous while their country was very sparsely peopled and devoted almost exclusively to agriculture; but now the tables are being turned, and there seems little need for the desperate protectionist policy they are adopting in order not only to establish among themselves sufficient cotton factories to supply all the wants of the people, but also to construct those factories with native iron, and by native, or, at any rate, naturalised labour. As regards other countries and other branches of trade, numberless instances might be adduced to show how England, from enjoying almost a monopoly as regards certain lines of enterprise, in tool making and in tool using, is now in some danger—perhaps

not yet very urgent or overwhelming—of losing its pre-eminence. When the new tide of manufacturing energy began, about a century ago, our country was especially favoured in possessing both the materials and the skill for making tools. It had also the skill to use them, and on these various grounds immense quantities of raw produce of all sorts were attracted hither in order to be manufactured for all the world. Thereby we have been vastly and permanently enriched; but during these hundred years we have been teaching, and by our example encouraging, the people of other countries—according to their opportunities and talents—first to use as skilfully as ourselves the tools we have made for them, and then even to make for themselves as good tools as we can provide them with.

In so far as this change is beneficial to the world at large, honest Englishmen have no reason to grumble at it. Nor need they even be seriously alarmed. As long as our people are intelligent and hard-working, they have nothing to fear from the worst crisis that can result from natural and legitimate causes. If tools of any sort can be produced and used better and more cheaply in other countries than in our own, it is to our own advantage no less than to that of the foreigners that they should be so produced and used. If they help to advance our neighbours in wealth and civilisation, that advance will beget in them new wants, in providing for which it should be our prerogative to take the lead. Capital, using the term in its widest and truest sense, is, in combination with natural agents, the material basis of all manufacturing and mercantile enterprise, and, in the long run, it is as certain to seek the places where it has most chance of growing, as is the plant to lean towards the sunlight. It carries with it, too, all that human energy can furnish towards supplementing and utilising the proffered gifts of Nature. English capital, however much of it may be squandered and perverted, however unfairly it may be portioned out among individuals, is a national possession which, being greater than that of any other nation, gives to the whole country an advantage over all others. At present it is being largely applied in benefiting other countries, in some respects apparently to our own detriment. As regards individuals and special trades, the detriment may be not only apparent, but real. But it is in the power of the people—not only those who handle most of its gold, but also those who supply most of its nerve and muscle, which are more potent than gold—to employ the national wealth in such ways as will maintain and augment the nation's happiness. If any of the old ways are becoming out of date and unproductive, new ways will have to be found and bravely followed.

At the same time, though economical laws cannot be overturned, they can be temporarily interfered with to such an extent as to cause serious mischief; and here it may be well to note, out of many dangers in the way of England's steady progress as a tool-manufacturing nation, the two which are just now the most prominent. For one, the English people, or large sections of them, are chiefly responsible. In respect of the other, they have to suffer mainly through the ignorance and folly of their foreign rivals.

It is one of the glories of England that it has inaugurated and persistently adhered to the policy of free trade. Its faith in the wisdom of that policy is just now being severely tried. There can be no doubt that much inconvenience is at present being caused in many quarters by the partial failure of the hopes built on the exploits of Mr. Cobden, Mr. Gladstone, and others, in 1860 and afterwards, in removing numerous hindrances to trade by an altogether new system of commercial treaties. The Anglo-French treaty, and others that quickly followed it, gave promise that the principle only partially enforced in them would soon be fully recognised. Instead of that, we find that in several foreign countries there has been a lamentable revival of protectionist theories. This is, perhaps, hardly to be wondered at, when we consider what showy arguments can be drawn by foreign sophists from the protectionist precedents of our own country, and from the ephemeral advantages among themselves to which they are able to point as resulting from the adoption of their views. It cannot be denied, for example, that the present generation of Austrian manufacturers will derive some immediate gain by forcing their Hungarian fellow-subjects to buy from them the costly and ill-constructed ploughs and other implements required in their agricultural pursuits, instead of obtaining cheaper and better articles from England, as they might do were there no restrictive tariff. By this arrangement, however, the Austrian manufacturer's gain merely hinders him from profiting as he might by competition with more experienced makers, while both the Hungarian and the Englishman are wantonly injured. The same short-sighted policy is upheld, though with fewer political complications, in Italy, Germany, and even France; and the folly is most preposterously

maintained in the United States. Exorbitant tariffs add enormously to the cost of nearly all American productions, with direct injury to the purchasers, and with benefit to the producers only so long as they do not need to obtain from foreign markets the goods that are not manufactured in their own country, or as they are not purchasers of the protected commodities in their own.

The other danger to be here referred to is one more complicated and far less easy of removal. The unparalleled success of nearly all departments of English manufacture which culminated in 1872 has not been altogether advantageous to the country. The working classes—who on the whole certainly obtained no more than their fair share of the exceptional profits on the transactions of that time—can hardly be blamed for stoutly and sullenly objecting to the reductions of wages since insisted on by their employers. How much justice there is in their complaints, and, on the other hand, what warrant the employers have for asserting that their businesses cannot be carried on without the prescribed reductions, it would be out of place to discuss here. It is only too evident, however, that the disputes between masters and men—which have become far too plentiful—are very disastrous to the country. It is also evident that, in demanding higher wages than are given for the same amount of labour in foreign workshops, the English artisans threaten seriously to embarrass the prospects of our trade. Belgium is not the only country that is now competing with England in some of the trading occupations in which it formerly excelled; but the remarks of Mr. Lumley, one of our Secretaries of Legation at Brussels, in his report on the commerce and industries of Belgium, dated January, 1878, fairly illustrate the usual opinion of the capitalist classes as to the present state of affairs. After pointing out other circumstances that have saved Belgian iron manufacturers from the actual ruin that has befallen some of their English rivals, Mr. Lumley attaches special importance to the lowness of the wage rate for which they have to provide. "Wages of skilled labour," he says, "which in 1872 stood at 11 francs, had fallen in 1876 to 5 francs, and are now standing at 4 francs. At 4 francs, or 3s. 4d. a day, it is difficult for an English workman to live and support a wife and family; but business will never flourish unless masters can find a sufficient inducement to invest capital. This the Belgian workmen, with their better education, have the good sense to see, and, as a rule, they accept work at such rates as they can obtain. It must be borne in mind, too, that the Belgian workman's day is of 12 hours. He works from six in the morning till six in the evening, time being given for meals, and he works six days a week. There is thus a saving on every element that enters into the cost of production; and the Belgian manufacturer is enabled to buy pig iron in England, pay for freight, and deliver that same iron manufactured into beams and girders in the most central parts of England, or even in the heart of the iron districts, at a lower price than it can be made for by English firms on the spot." The English working man might think it better to starve than to submit to such conditions of life as are imposed on the Belgians; and he may, if he chooses, quote the authority of political economists, from Ricardo downwards, for holding that the wage rate, measured by the cost of living and the essentials of comfort, is a much less variable element in the problem at issue than the rate of interest on profit insisted upon by capitalists. If English tool making is in danger from the enterprise of other countries, it may be to a great extent because in those other countries capitalists are satisfied with much smaller returns for their investments than in England.

COTTON.—VIII.

CARDING ENGINES.

By David Bremner, Author of "The Industries of Scotland."

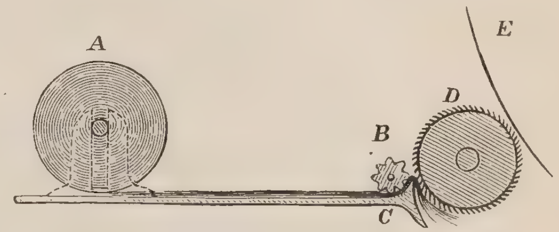
ARKWRIGHT'S carding engine in its first form accomplished its work in a fairly satisfactory manner, but until it was supplied with the continuous feed and delivery apparatus its utility was much restricted. It consisted of a cylinder covered with cards, over which were placed a number of narrow boards covered in the same way. The cards on the boards—or "flats," as they came to be called—were placed close down to those on the cylinder, and the cotton was disentangled by

being drawn by the cards on the cylinder against the stationary cards on the "flats." The wool was fed in by hand between fluted rollers, and when sufficiently carded, the machine was stopped, and the wool removed with hand cards. The first improvement in the machine at this stage was the addition of a card-covered roller of smaller diameter than the cylinder. This carried the carding to a higher degree of perfection, and as the action of the roller cleared the cylinder of its wool, it was called the "doffer." When the doffer became sufficiently loaded, the machine was stopped as before, and the wool removed. These stoppages entailed great loss of time; but the work of improvement, once having been started, was speedily carried to a successful issue. Arkwright, as stated in a previous chapter, devised a mode of feeding the carding engine and taking off the wool in a continuous manner. The mechanical carder was now a matter of fact, and was capable of being worked by water or steam. For nearly half a century, the machine underwent no change. Usually the wool was carded twice, as it still is for the higher counts of yarn—the first time on the "breaker carding engine," and the second time on the "finisher," the latter being furnished with finer cards than the former. The machines were fed with laps made on the scutcher, and delivered the wool in the form of a sliver or soft ribbon, which was received in tall tin cans.

As the cotton manufacture extended, and the demands upon the producing appliances increased, the possibility of making the carding engine more expeditious in its operation received some consideration. It was also thought desirable that the waste entailed by the machines then in use should be reduced, and that some mechanical mode of cleaning the cards should be discovered. The flats had to be "stripped" at intervals—that is, they had to be taken off the machine, and the tangled tufts of wool which they picked from the mass combed out by means of a hand card. At less frequent intervals the cards on the cylinder and doffer had to be similarly cleaned. Occasionally, also, the points of the cards had to be sharpened. These operations required to be carefully done by skilled workmen. It was difficult, however, to get the strippers and grinders to do their work satisfactorily. The occupation was an unhealthy one, owing to the dust which was inhaled; and the men engaged in it were too often indifferent to the interests of their employers. At first sight, the problem of mechanical stripping seemed hopeless; but the inventive genius of the country which had done so much already for the cotton manufacture, did not shrink from attempting to solve it. Mr. Alexander Buchanan, a partner in the firm of Messrs. Finlay and Co., Catrine Mills, Ayrshire, was the first patentee of a mechanical stripper. This was in 1823. His apparatus displayed great ingenuity, and the principle of it is retained in some of the most approved machines of this day. The flats were so mounted as to admit of their being raised singly from their positions, and both ends of each were furnished with studs, on which a radial arm, working on each end of the main cylinder axle, acted so as to raise the flats in succession, and present them to the action of a revolving brush, which cleaned them thoroughly. The apparatus was perfectly automatic, and its action was regarded with much admiration, as it raised the flat, turned it over, held it to the brush, and then restored it to its place. The brush was cleaned by means of a self-acting comb, and finally the knotted fibres were removed from the latter by a slip of copper, and deposited in a receptacle conveniently placed. Though the merits of Mr. Buchanan's invention were generally recognised, it was not adopted by many spinners. The cost of fitting it to the existing machines was considerable, and, besides, the work-people were strongly averse to its adoption. About the year 1834, Mr. James Smith, managing partner of the Deanston Cotton Works, Scotland, visited Manchester to introduce to the notice of the manufacturers of that city a self-stripping carding engine, and also a self-acting spinning-mule. Both inventions were favourably received. The carding engine presented several novel features. The main cylinder was of larger dimensions than usual, and was placed high in the framing, in order to make room beneath for two sets of feed and delivery apparatus. The wool was supplied to the cylinder at two points, in very thin films, and thus its more complete dispersion over the cards was secured. The chief novelty, however, was the arranging of the flats on a pair of endless chains, which travelled over the upper section of the cylinder. The chains passed over three small rollers, and the flats were guided to their proper distance from the cylinder by grooved plates, in which their ends were made to slide. A slow motion was given to the chains, and as the flats passed from the cylinder they were of course turned face up, and in that position were stripped by a revolving brush, which was in turn cleaned in the same way as the brush in

Mr. Buchanan's machine. It is a coincidence worth mentioning, that when Mr. Smith appeared in Manchester with his inventions, Mr. Evan Leigh, a well-known mechanician of that city, was engaged in working out an idea for the construction of a self-stripping carding engine on nearly the same plan as Mr. Smith's machine. When Mr. Smith's patent had run out, Mr. Leigh reverted to the subject of self-stripping carders, and in 1850 and 1852 obtained patents for machines which showed a marked improvement on Mr. Smith's. In subsequent years he effected further amendments, and now his carding engine is in extensive use. The general principles of this and other varieties of carding machines are the same as those laid down by the earlier inventors, the only difference being in points of detail which give greater completeness to the mechanism. Most makers of cotton machinery have some specialty or other in their carders, and in a general way these have something to commend them.

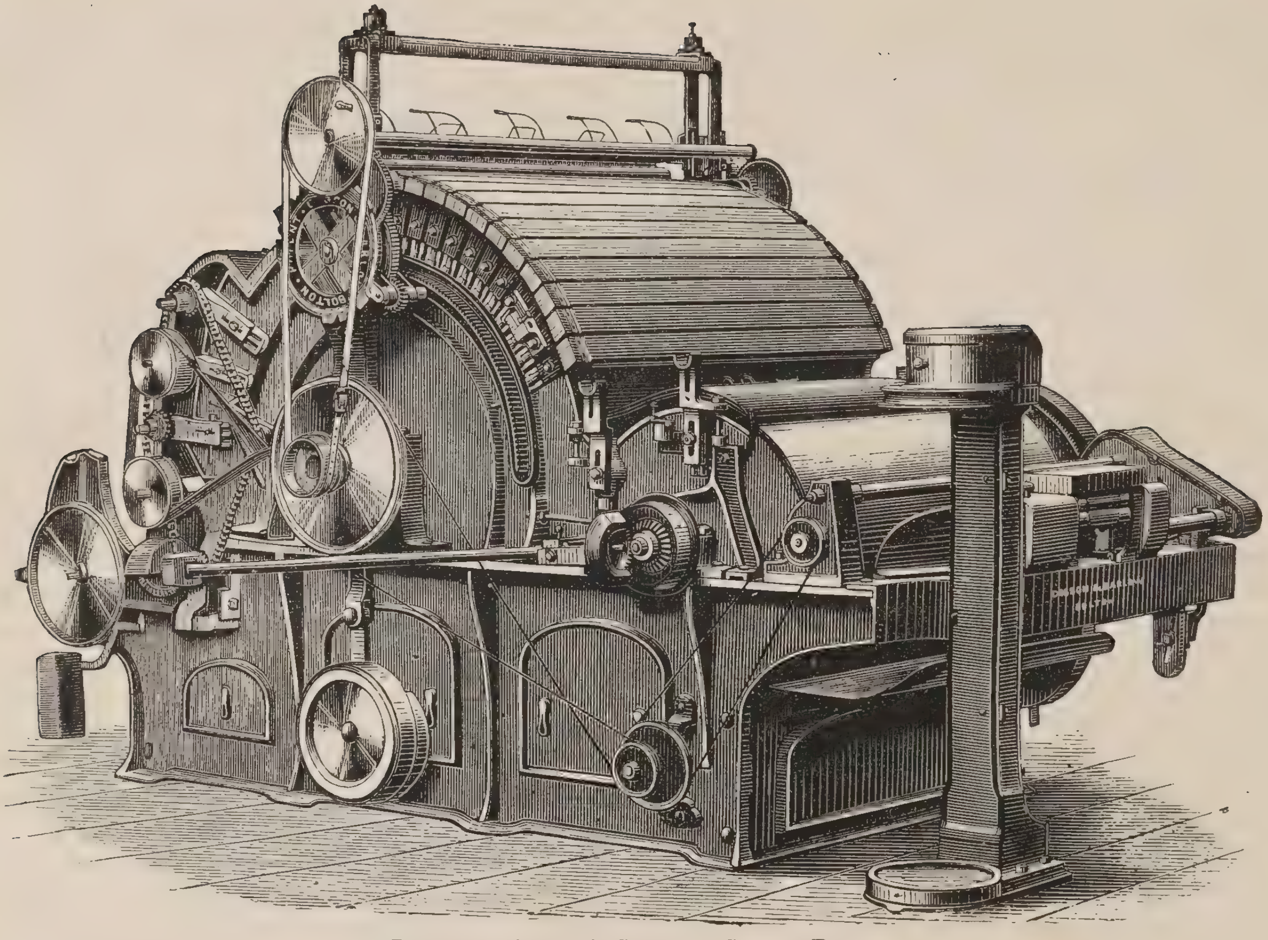
Several inventors have endeavoured to get rid of the flats by introducing small rollers covered with cards, and made to revolve at a higher velocity than the main cylinder against which they worked. For keeping these small rollers clean, "dirt rollers" were attached to the machine and were constantly engaged in stripping out the knots and other waste. This system was found to answer fairly well in dealing with inferior qualities of cotton; but it destroyed the long and fine fibre. Consequently it came into only limited use. The most approved engines now employed, however, are constructed on the composite principle, and have several small carding rollers in addition to the flats. The engraving on the next page represents one of the latest forms of carding engine of this class, as shown at the Paris Exhibition of 1878, by Messrs. Dobson and Barlow, of Bolton. To those who are familiar with cotton machinery this carder needs little description to make its special points apparent; but for the benefit of those of our readers who have not that advantage, and yet may desire to have some idea of the construction and operation of the machine, we shall briefly describe it. As shown in the engraving, the machine occupies a diagonal position, and consequently one side and one end are exposed to view. The side seen is that where the working part of the stripping apparatus is placed, and the end is that at which the cotton, after being carded, passes from the machine. Beginning at the rear end, the first thing to be noticed is a projecting shoulder on each side of the frame, having slits into which the ends of the axle holding a roll of lapped cotton are placed. The lap is led on to a metal plate peculiarly curved at its inner edge, and between this plate and a fluted roller the cotton is



SECTION OF CARD-ENGINE FEEDING APPARATUS.

(A) Roll of Lap; (B) Fluted Feed-Roller, 2 in. diam.; (C) Curved Plate, over the lip of which the Cotton is held till pulled away by the strong carding on (D) the Taker-in; (E) Segment of main Cylinder.

slowly drawn in, and presented to a roller covered with carding of a special kind. This roller, which is 9 inches in diameter, is called the "taker-in," and its duty is to pull the fibres from the grasp of the fluted roller and plate, and transfer them to the carding cylinder in an approximately even layer. Above the taker-in, and in contact with the main cylinder, there are two carding rollers, 6 inches in diameter; and connected with each of these is a clearing roller, 4 inches in diameter. These rollers, acting in conjunction with the cards on the cylinder, and moving at a much slower rate, comb the wool out again and again; and as the fibres are disentangled to a considerable extent they are carried by the cylinder to the flats which occupy the upper part of the machine. The flats, being stationary, seize all entanglements and hold them until the cylinder cards have opened them up. When the cylinder passes the flats, it is covered with an even fleece of wool free from knots or specks. This fleece is removed from it by the doffing cylinder, which is in turn relieved of its load by the crank-and-comb arrangement already alluded to as having been invented by Arkwright. The comb is a thin bar of steel, one edge of which is serrated. It is mounted on a crank which gives it an exceedingly rapid vibratory motion—so rapid, indeed, that, in order to prevent the heating and wear of the working parts, they are now inclosed in chambers filled with oil. The comb is pressed down on the wires of the doffer, and as the latter revolves the cotton is stripped from it and passes in an unbroken fleece to a funnel, where it is gathered together as in one's hand, and reduced to the form of a soft untwisted rope or sliver, which is received in a tall metal can, the stand for which is seen near the end of the machine. The stripping apparatus next claims attention; but no description can convey anything like an idea of its ingenious

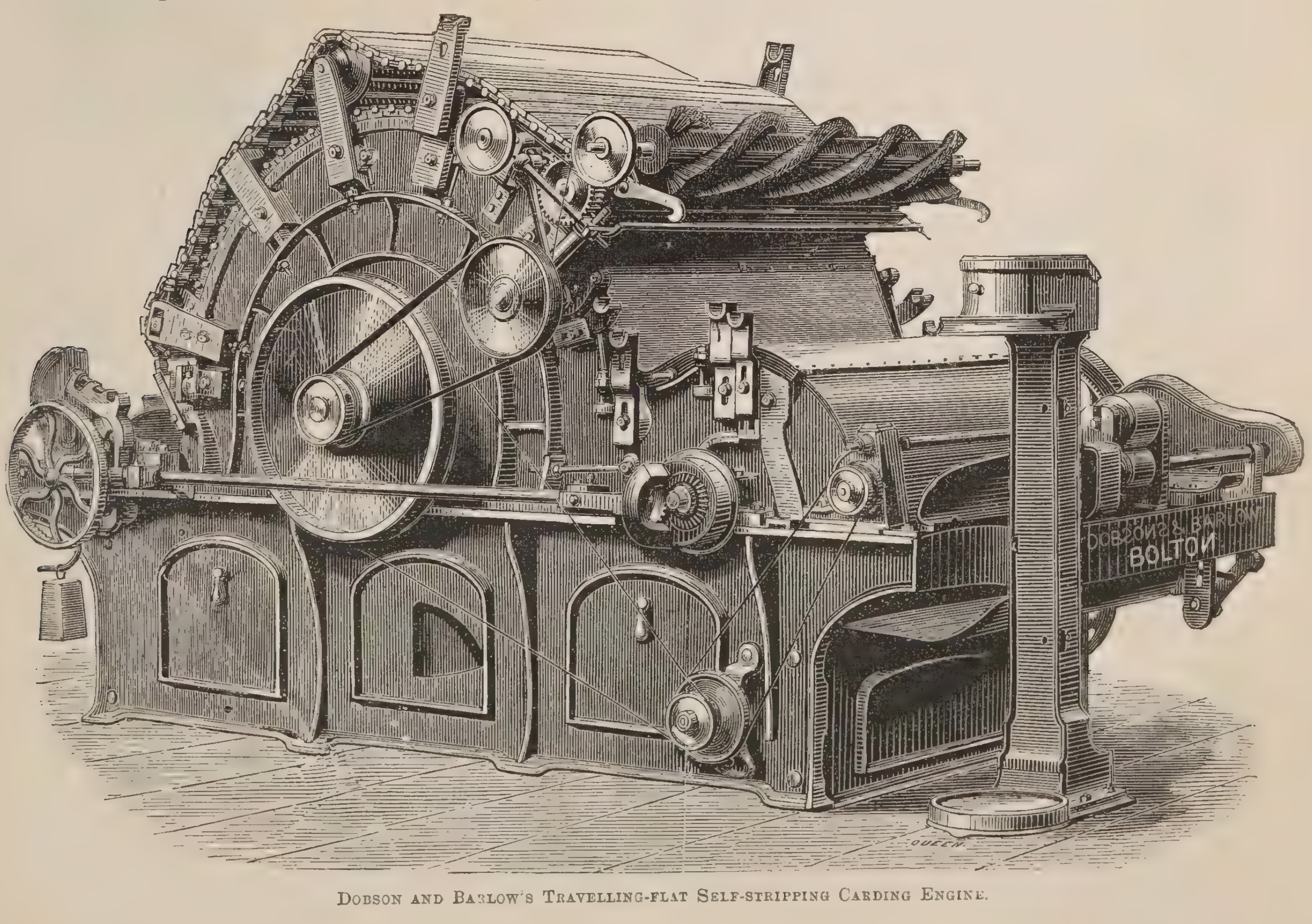


DOBSON AND BARLOW'S COMPOSITE CARDING ENGINE.

form and mode of working. It is an adaptation of the principle of stripping invented a number of years ago by an American named Wellman. On either end of the main cylinder axle a strong beam of iron is centred. The upper arm of this beam carries the apparatus for raising and stripping the flats, and the lower bears a counterweight. If we suppose the machine to start from the position in which it is shown, what would take place would be this:—The stripping gear would move forward along the arc formed by the tops of the flats. Certain of the latter would be lifted out of their beds in succession, and while firmly held, would have a stripping card drawn under them, whereby all the knots and impurities they had picked out of the cotton would be removed. After such operation the stripping card itself is cleaned. We have said "certain" flats would be operated upon, and herein lies one of the important features of the machine. The first of the series of flats which the cotton comes into contact with in its passage through the machine naturally has the best chance of seizing knots, &c., and, consequently, if the flats were to be allowed to remain unstripped for a little time, it would be found on examination that they contained accumulations of waste decreasing in proportion as their positions were removed from first contact with the wool. When stripping was done by the hand, it was usual to strip a certain proportion of the flats more frequently than the others; and a difficulty with the inventors of mechanical strippers was to find a combination of movements that would imitate the hand practice. In the machine under notice this difficulty has been completely mastered, and the stripping is done in an unfailing rotation. Of the sixteen flats, the first division of six is stripped thrice in a given time, the second division of five twice, and the third division of five once. The mechanical arrangement whereby this is accomplished is exceedingly pretty in its operation. The rotation followed in six successive passages of the stripper over the space occupied by the flats is this:—On the first journey the flats numbered 1, 3, 5, 9, 11, and 15, are stripped; second journey, 2, 4, 6, 10, 12; third, 1, 3, 5, 7, 13; fourth, 2, 4, 6, 8, 14; fifth, 1, 3, 5, 7, 9, 11; and sixth, 2, 4, 6, 8, 10, 16. The apparatus admits of adjustment to any other rotation.

Messrs. Dobson and Barlow, and Messrs. Platt Brothers and Co. (Limited), of Oldham, also exhibited at Paris self-stripping machines on the travelling flat principle, for which many spinners have a preference. In these machines the flats are attached to an endless chain, and as they leave the cylinder in rotation, are stripped by a revolving brush. One great advantage of this form of machine is that the wires may be ground as well as stripped while carding is going on. Messrs. Hetherington and Sons, of Manchester, are the makers of a carding engine upon the stationary flat principle, which has attracted much favourable notice. In it, the flats, on being lifted from their beds in rotation, are turned over till the wire comes uppermost, when a stripping flat is passed over them. Provision is also made for grinding the wires while the machine is in motion. The stripping is so expeditiously performed that each flat is absent from the cylinder only six seconds. So perfect are the four machines we have specially mentioned, that they leave little to be desired on the part of the spinner.

Among the details of carding machines, none are more important than the size and arrangement of the wire points which effect the separation of the fibre. These are made of hard-drawn iron wire, and are now usually inserted in an indiarubber foundation, or a combination of cloth and india-rubber. In the early days of the cotton manufacture, the wire points were set in leather by hand, and it was an exceedingly tedious occupation. Mr. Kay, of Bury, was the first to produce a machine for doing this work, and it was a remarkably ingenious contrivance. This machine was, however, improved upon by an American, and Mr. Dyer, of Manchester, obtained the patent rights for this country. Mr. James Walter effected some important improvements on the American machine, and it now does its work in a most satisfactory manner. A stout ribbon of vulcanised rubber is placed on a bobbin, and one end of it is passed into the machine, which, on being set in motion, pierces the rubber, forms the points from a roll of wire, and inserts them in their places at a rapid rate. The machine insures absolute uniformity in the length of the points and the angle at which they are bent—matters essential to good work. The points are made of various thicknesses of wire, according to



Dobson and Barlow's Travelling-flat Self-stripping Carding Engine.

the position they are to occupy in the machine, and the quality of cotton to be dealt with. Card clothing also varies in the number of wire points upon a given space, and is designated accordingly. If there are one hundred wires upon four inches it is called No. 100; one hundred and twenty, No. 120, and so on. Generally speaking, the "taker-in" is covered with either a very strong card or with saw-tooth filleting in which the ground-work is leather instead of indiarubber. The main cylinder, when adapted to deal with cotton for the coarser numbers of yarn, is covered with No. 90, and when the cotton is intended for finer yarns, Nos. 100 or 110 are used. The carding rollers, in that case, have No. 90, and the clearers No. 100; whilst the rule as to the doffer is, that its cards should be twenty numbers finer than those of the main cylinder. The fine cards on the latter enable the comb to take off the carded cotton in a finer and more regular web, and the wool, having been already subjected to the operation of the rollers and flats, has no entanglements likely to injure the more delicate wires. There are two forms of card clothing for cylinders—namely, sheets and fillets. The former are about 4 or 5 inches in width, and of a length suited to the length of the cylinder; the fillets are usually about 2 inches wide, and in length sufficient to cover the cylinder when wound upon it spirally. Filleting is generally used for cylinders and rollers, and the sheets for the flats. It is important that the card points should be kept well sharpened; otherwise, it would be impossible to produce a clean, regular fleece. The wires on the flats, in machines which are not self-grinding, are sharpened about once a fortnight, by being subjected to the action of a roller covered with emery; and the main cylinder and doffers are ground about once a month, by mounting in contact with an emery roller, and driving the cylinder and roller in opposite directions. Equally important with the sharpening of the cards is their adjustment, or "setting," so as to insure that the points on the main cylinder are exactly parallel with those on the rollers and flats, and as close as possible together without actually touching. For the purpose of adjustment, the flats are furnished with screws by which they may be raised from or lowered to the cylinder. Sometimes a thin slip of iron is used in setting, to determine whether the card points are in contact or not; but the skilled workman generally relies on his ear for ascertaining whether the points are clear. The relative surface speed of the feed rollers and the doffer is usually as 1 to 100, so that 1 yard of lap is converted into 100 yards of sliver. This draught may be increased or diminished by changing the pinions which drive the feed rollers. The surface velocity of the main cylinder is from 15,000 to 16,000 feet per minute, whilst that of the doffer does not exceed 70 or 80. The carding rollers require to revolve at such a speed as will bring every part of their circumference into contact with the clearing rollers sufficiently often to prevent the cotton fibre gathering upon them in too thick a film. The clearers, again, must overrun considerably the carding rollers, so as to clear them out thoroughly.

To understand what a nice operation carding is, one has but to glance at the pages of "The Science of Cotton Spinning," by the late Mr. James Hyde, a gentleman who was not only a practical cotton spinner, but was well versed in the construction of all kinds of cotton machinery. Mr. Hyde gives copious technical details of no fewer than seven carding engines suitable for dealing respectively with cotton intended for yarns of from 20 up to 350 hanks to the pound. Of these he gives the dimensions of the various working parts, the number of their revolutions, the counts of the card points, the number of teeth in the driving wheels, the extent of the draught between the doffer and the feed roller, the diameter and revolution of the various pulleys, the length of sliver which each machine is capable of producing in a week, the weight per yard of the same, and so forth. The first engine of the series which he describes is adapted to carding cotton for 20-hank yarn, and consists of main cylinder, doffer, six carding and six clearing rollers, licker-in, feed roller, drawing box, plunger, and can motion. The main cylinder is 48 inches in diameter and 49 inches wide; the card points vary from No. 60 on the clearing rollers to No. 90 on the doffer, and the machine is capable of getting through 1,086 lb. of cotton per week of 50 hours. The last engine of the series is one to card for 350-hank yarn. It consists of main cylinder, doffer, licker-in, 14 top cards, feed rollers and delivering rollers. The main cylinder is 36 inches in diameter, and only 19 wide. The card-points vary from No. 80 on the licker-in to No. 140 on the doffer, and the machine's work in a week of 50 hours is only 25 lb.

SHIP BUILDING.—IX.

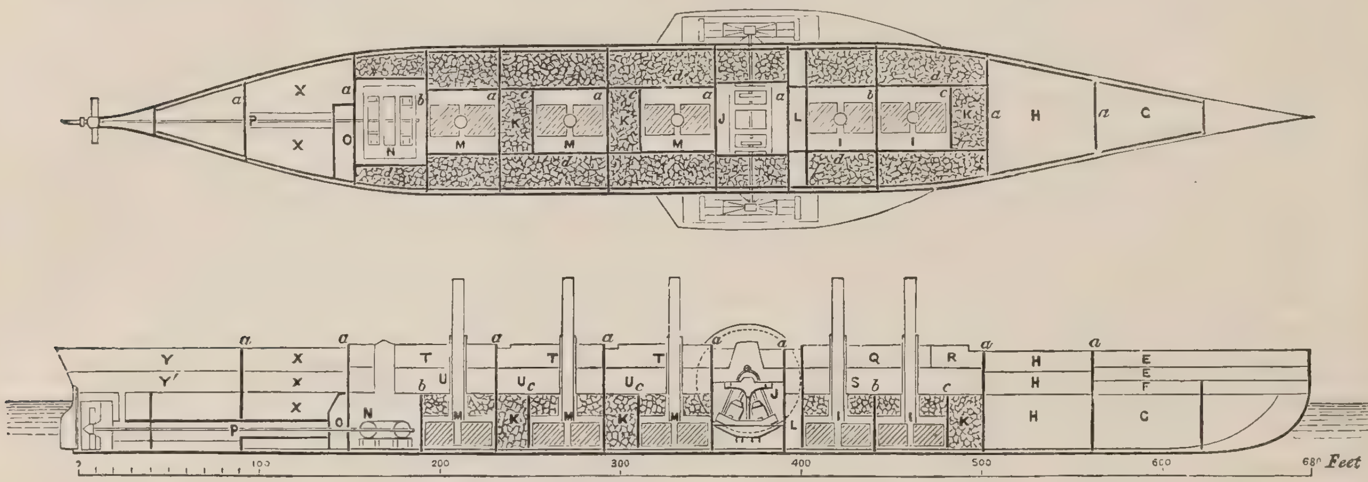
THE "GREAT EASTERN."

A REVIEW of the progress and present position of iron ship building such as we have undertaken in the preceding articles, necessarily conducts to the special consideration of the *Great Eastern.* Twenty years have elapsed since that remarkable vessel was floated on the Thames, yet she is still unapproached in size and weight by the largest vessels which have been built either for war or for commerce. The aggregate weight of three of the heaviest ironclads, or three of the finest Atlantic mail steamers, would only equal that of this monster ship; and at the time she was built her relative proportions were even more considerable than they now appear. During the Crimean war the famous troop ship *Himalaya* was one of the largest and fastest merchant steamers afloat; she was only half as long, and about one-seventh as heavy, as the *Great Eastern.* When the latter ship was launched, the Royal Navy boasted of the possession of towering three-deckers, carrying 131 guns and manned by 1,100 men; but the largest of these men-of-war was considerably less than one-half as long, and not more than one-fourth as heavy, as the *Great Eastern.* In view of these facts it may fairly be asked, Why was the *Great Eastern* made so large? Was it to fulfil some well-considered scheme, or was it an ambitious freak on the part of her designer to surpass all rivals in the grandeur of his work? Fortunately, we have the means of answering these questions from documents prepared before the ship was built by the great engineer, Mr. I. K. Brunel, with whom the design originated; and any one who will consult them cannot fail to be impressed with the conviction that the design of no ship could have been more carefully thought out, in its details as well as its main features, before any part of the construction was taken in hand. The objects aimed at may have been, and we think they were, mistaken—the conditions which ruled the design are subjects for fair criticism; but having regard to the circumstances under which the ship was built, her great size was a necessary consequence of the service she was expected to perform. This was nothing less than the circumnavigation of the globe, the ship carrying from England coals sufficient to enable her to steam the whole distance, and having besides a reasonable amount of cargo-carrying capacity, as well as accommodation for a large number of passengers. To carry out this programme the dimensions chosen were as follows:—Length, 680 feet; breadth, 82½ feet; depth from upper deck to keel, 58 feet; draught of water when fully laden, 30 feet; and corresponding total weight of ship and lading, nearly 28,000 tons. In order to attain the desired average speed of 14 to 15 knots per hour, it was considered necessary to have engines capable of developing from 10,000 to 12,000 horse-power, applied to drive a screw propeller placed at the stern of the ship, and two large paddle-wheels placed nearly amidships. Separate engines were employed to drive each of these propellers, and the paddle-wheels on opposite sides of the ship could be disconnected and worked at different speeds, or in opposite directions, in order to increase the manœuvring power of the huge floating structure. The sail power was subordinated to the steaming; but it formed a valuable auxiliary, and consisted of nearly 60,000 square feet of canvas, carried on five masts. It was never intended that the vessel should proceed under sail alone—she was essentially a steamer.

The engravings on the next page of the longitudinal section and plan of the *Great Eastern* will furnish all necessary information respecting the internal arrangements of the ship. Rather more than half the length (350 feet) of the ship is occupied by engines, boilers, and coals; and great pains were taken to facilitate the supply of coals from the bunkers to the stoke holds. In a case where the coal supply was intended to be 10,000 tons this was a matter of great practical importance. The cargo holds are situated before and abaft the central spaces containing machinery and coals: these spaces are bounded by a deck 34 feet above the bottom of the ship, and upon this deck and the decks above it are placed the saloons and passenger accommodation. She was intended to carry 4,000 passengers, and a crew of 400 men, when fully laden with cargo, and to transport 10,000 troops on an emergency. In July, 1861, when the forces in Canada were increased in consequence of the *Trent* affair, the *Great Eastern* actually carried 2,500 troops to Quebec, but they were nearly all berthed in the cargo spaces, the passenger cabins being but little utilised. Altogether 3,000 souls, and 200 artillery

horses, were carried on this voyage, and she was never afterwards so fully occupied by passengers. General opinion has, in fact, always declared against the embarkation of such a force as 10,000 troops in a single vessel, the risks to be run being considered too great. By distributing the force in several ships, the chances of serious disaster are lessened, for if one ship miscarries the others may escape accident. Hence it is not surprising that the Government have never considered it desirable to acquire the *Great Eastern*, while she has been but rarely employed on the public service. On the other hand, there is little prospect that if employed on any route, the *Great Eastern* could ever have secured 4,000 passengers, without considerable delays, and on the Atlantic line she never obtained more than a small fraction of that number. In fact, an examination of the plans must conduct to the conclusion that far too large a proportion of the space was devoted to coal-stowage and passenger accommodation, the cargo-carrying capacity being relatively small, although absolutely great. One of the heaviest cargoes she ever carried before being employed in laying submarine cables was in 1862, when she returned from America with more than 5,000 tons of cargo on board; but this immense weight was only *one-fifth* of her total weight at that time.

In a commercial sense the great ship has undoubtedly been an utter failure, and it has been stated on good authority that between 1853 and 1869 one million sterling had been lost upon her by the various proprietors who had attempted to work her. Nor is it difficult on an impartial review of her design and subsequent history to discover the causes of this failure. First of all, Mr. Brunel, despite his remarkable foresight, did not realise the changes which have been produced in a single generation by the progress of steam navigation. Coal mines have been opened up in all parts of the world; and even if it once may have been, it is now no longer necessary or desirable for a steamer to carry coals for a return voyage, either from India or Australia; in fact, the proverbial folly of "carrying coals to Newcastle" may be applied to an Australian as well as to an English coal field. Further, the improvements in marine engineering which have been introduced since the *Great Eastern* was designed, have rendered possible large economies of coal consumption. It is said that the engines fitted to the ship consumed about 360 tons of coal per day when the speed averaged about 13 knots per hour; but if the modern type of compound engine had been fitted, the rate of consumption would not have exceeded 180 tons. Mr. Brunel appears to have been too sanguine in his estimate of the speed and coal consumption, and this is scarcely surprising when the entire departure from previous examples of steam-ships is remembered. He hoped that the ship would make the passage to Australia in 36 days, which would have required an average speed of 14 knots per hour, and this speed was to be purchased by the consumption of 200 tons of coal per day. With engines of the modern type his hopes may have been more nearly realised, and it has been reported that the present proprietors (1878) of the ship have

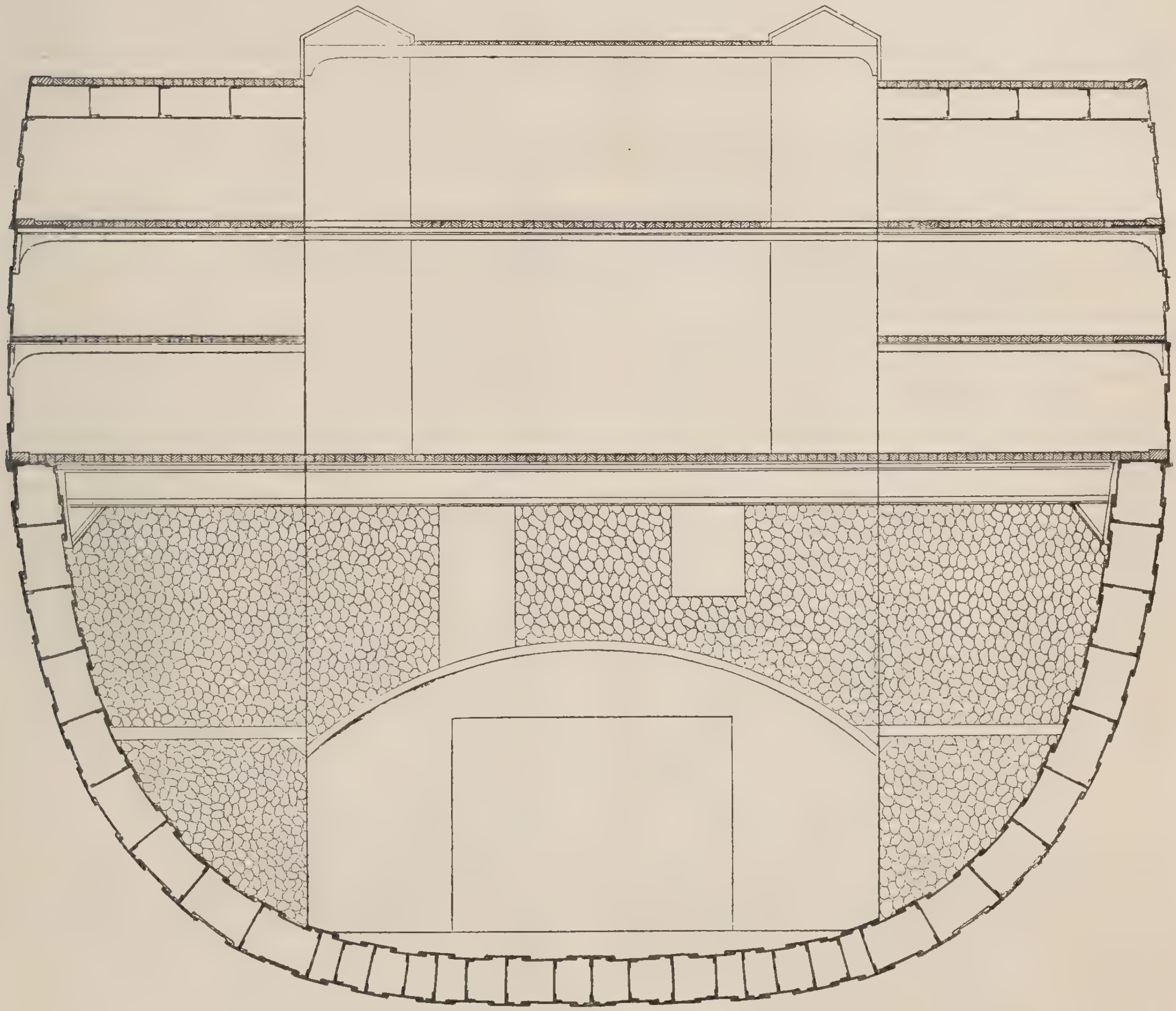


LONGITUDINAL SECTION AND PLAN OF THE "GREAT EASTERN."

(*a*) Complete Transverse Watertight Bulk-head; (*b*) Transverse Watertight Bulk-heads complete up to Water-line; (*c*) Partial Transverse Bulk-heads; (*d*) Longitudinal Bulk-heads; (E) Cable Decks; (F) Chain Cable Lockers, &c.; (G) Ice-house, Stores, &c.; (H) Forward Cargo Space; (I) Paddle Boiler Rooms; (J) Paddle Engines; (K) Cross Coal Bunkers; (L) Paddle Auxiliary Engines; (M) Screw Boiler Rooms; (N) Screw Engines; (O) Screw Auxiliary Engines; (P) Screw Alleys; (Q) Grand Saloon; (R) Ladies' Saloon; (S U) Lower Saloons; (T) Upper Saloons; (X) Aft Cargo Space; (Y) Aft Cable Deck, &c.; (Y′) Deck for Auxiliary Tiller, &c.

contemplated "compounding" the engines in order to save fuel, but no change of this kind has yet been begun.

The chief cause of failure in a commercial sense was, however, the practical impossibility of securing such an enormous complement of passengers and cargo as was estimated to be necessary in order to cover working expenses and earn a profit. Six thousand tons of dead weight was the quantity of cargo required; but to ship such a quantity must at any time have involved serious delays in port, and as a matter of fact merchants and insurers were not ready to run the risks involved in embarking so much in a single bottom. On the whole, therefore, two or three steamers of moderate size, and with modern types of engines, could be more profitably employed to carry the same number of passengers and the same aggregate dead weight of cargo as those for which the *Great Eastern* was designed. During the last three or four years strenuous efforts have been made to improve the steam-ship service between England and Australia, and competition has been keen, not merely between steamers and sailing-ships, but between different lines of steamers. Some of these latter now make the passage—*viâ* the Cape—in from 40 to 45 days, and it is proposed to abridge this time to 36 days; but no one has imagined it desirable to employ ships exceeding about one-fourth the weight of the *Great Eastern.* Another noteworthy circumstance is the successful employment for many years on the Australian line of the *Great Britain*—Mr. Brunel's earlier creation—designed for the Atlantic trade. The *Great Britain* made some excellent passages, but not approaching those recently made; and her success must be largely



CROSS SECTION, THROUGH THE BOILER ROOM, OF THE "GREAT EASTERN."

attributed to her good performance under sail. She was heavily rigged, and could consequently economise fuel to a very considerable extent.

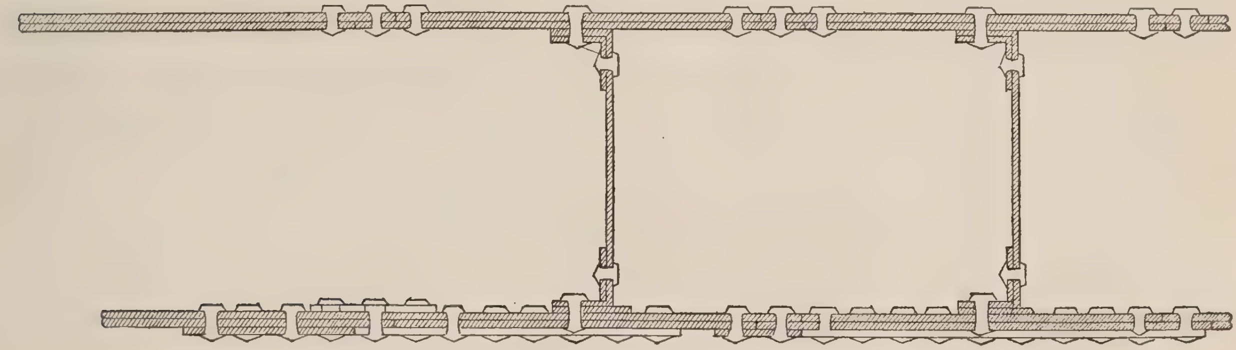
When one turns from the commercial aspect to the consideration of the structural details of this remarkable ship, adverse criticism comes to an end. It may be questioned if any more admirable example can be found of the successful application of wrought iron in ship building, or of the association of lightness with strength in a sea-going ship. The weight of iron used in the hull is said to have been 6,250 tons, and this material must have supplied the strength required to carry the load of 26,500 tons which was put upon it when the vessel left England in 1868 to lay the cable from Bombay to Aden. Besides the iron in the hull, there is about 2,500 tons of wood, in decks, cabins, and fittings of all kinds; but this wood can add little to the structural strength. Including both wood and iron in one total for hull, we have 8,750 tons, or about 27 per cent. of the total weight of ship and lading: the corresponding figures for good specimens of mercantile steam-ships of the present day give an average of about 30 per cent. for the weight of hull, and show a clear gain of 3 to 4 per cent. for the *Great Eastern*. There can, of course, be no question of the sufficiency of strength of a ship which has performed such work as has fallen to the lot of the *Great Eastern*, or passed through so many trials and dangers. From 1860 to 1863 she made nine voyages across the Atlantic. On one occasion she laid helpless for hours in a terrific storm, with her rudder disabled and paddle-wheels broken. On another voyage she ran aground and seriously damaged her bottom; but on neither occasion did she sustain vital injuries, as an ordinary vessel would probably have done. Since 1865 she has laid five cables across the Atlantic, and one from Bombay to Aden, performing these arduous services without a sign of weakness or distress in the structure. It will be interesting to examine briefly the principal features in the construction of the hull, by which these good results have been obtained. The engraving of the cross section through the boiler room will assist our explanations.

The outer skin of the ship is formed in the usual manner of iron plates $\frac{3}{4}$ of an inch thick. At a distance of 3 feet within this outer skin there is an inner skin of equal thickness, which rises to a height of 34 feet from the bottom of the ship, or about 4 feet above the intended load-line for the ship when fully laden. Between these two skins a large number of longitudinal frames or girders are fitted; in fact, this lower part of the vessel is a cellular structure, capable of resisting enormous tensile and compressive strains. This "double bottom" is not merely a source of strength; it is also a means of safety and convenience. During her employment on the trans-Atlantic service in 1862, an accident happened which forcibly illustrated the value of the double bottom. The ship was being stopped at the entrance to Long Island Sound to take a pilot on board, when she ran over a reef of rocks, and tore a hole in her outer skin which was afterwards discovered to be 80 feet long and 10 feet wide. The inner skin, however, remained intact, and although several of the compartments of the double bottom were filled with water, no water entered the hold, nor was the ship placed in the slightest danger. Had she been built with a single skin, like ordinary iron ships, a similar accident might have proved fatal. Further, as a receptacle for water ballast, the double bottom is a great convenience: and it will hold no less than 2,500 tons. The *Great Eastern* was not the first ship possessed of these advantages, but they were more fully developed in her than in preceding vessels, and became better known in consequence. A cellular double bottom forms an important feature in all iron-hulled armoured ships of recent date.

The cellular system of construction carried out in the lower part of the ship was undoubtedly a result of the experiments which had been made by Mr. Fairbairn and Mr. Hodgkinson on behalf of Mr. Robert Stephenson before the construction of the Menai and Conway tubular bridges. Mr. Brunel was not content, however, to limit the application of the cellular system to the lower part of the ship, but extended it to the upper deck, which is nothing more nor less than an imitation of the top flange of the Menai Bridge. This deck is altogether exceptional, and its construction will be better understood from the enlarged sectional drawing on p. 267. There are no beams lying transversely, the supports being longitudinal girders extending from one transverse bulk-head to another. Upon the upper and under sides of these girders strong iron plating is worked in two layers, each $\frac{1}{2}$ inch thick; and the combination is admirably adapted to resist compressive as well as tensile strains. The upper surface of the iron deck is plane, having no sheer or round-up; but a wood deck flat is laid upon it, and this has some transverse curvature,

in order to clear the water. It will be noticed that the cellular deck is constructed only on either side of the central openings for hatchways, ventilation, &c., and the reason will be obvious. Continuity of strength is an impossibility at this central space, and it would only be a waste of material to construct a strong deck which would be pierced at frequent intervals.

Having provided for the longitudinal strength of the top and bottom of the ship by these arrangements, Mr. Brunel had to secure an efficient connection between top and bottom, a sufficiency of transverse strength, and a proper amount of stiffness for the nearly vertical portion of the side plating between the lower deck and the upper deck. Throughout the middle half of the length there are strong longitudinal bulk-heads, forming the sides of the engine room and stoke holds, and reaching from the upper deck to the bottom of the ship. These longitudinal bulk-heads add to the longitudinal strength, as well as connect the upper and lower parts of the structure. The transverse strength is almost entirely supplied by transverse bulk-heads, of which there are no less than ten. Eight of these extend to the upper deck, and two to the lower deck; the longitudinal frames distribute their strength to the spaces intervening between the bulk-heads. This is a remarkable contrast to the common system of construction, exemplified on page 185, and previously described; but it has stood the test of actual service remarkably well, to the surprise of many persons who advocated the use of closely-spaced transverse ribs. These bulk-heads, both transverse and longitudinal, form water-tight partitions, and effect a sub-division of the hold space, which is most conducive to safety in case of a serious accident that should break through the inner as well as outer skins, and admit water into one or more compartments. Not many ships in the mercantile marine can be compared in this respect with the *Great Eastern;* and if the outline sketches on page 264 are studied, the reader cannot fail to note how the necessities for stowage and accommodation are made to contribute to this end. Water-tight sub-division in ordinary iron ships does not receive the attention it deserves, the general opinion being that stowage of the hold is seriously hampered by the introduction of numerous bulk-heads; but in passenger ships, at least, considerations of safety surely should be paramount. We shall recur to this subject hereafter.



Enlarged Section of the Upper Deck of the "Great Eastern."

The intermediate decks of the *Great Eastern* do not present any features calling for special mention; they are in fact treated mainly as platforms rather than as important contributaries to the structural strength. Not that they are of little value in the maintenance of the form of the ship; for they stiffen the sides, and tie together the parts to which the deck beams and plating are connected, besides distributing the strength of transverse bulk-heads. Further stiffness, in the vertical sense, is given to the sides where it is considered desirable by means of deep frames, or "partial bulk-heads," somewhat similar to those described on page 204; but these strengtheners are comparatively few.

These are the principal features in the structure of the *Great Eastern;* into the many interesting and special features of her outfit and equipment we have no space to enter. Nor can we dwell upon the magnitude of the operations of building and launching such a monster. It must be stated, however, that the stoppage in launching, which exercised so seriously prejudicial an effect upon the prospects of the ship, was due to the attempt to launch upon iron "ways," or sliding surfaces, instead of the ordinary wood ways with well-greased surfaces.

Mr. Brunel no doubt hoped to have secured some advantages by his departure from precedent, and it is but fair to him to note that before deciding upon the plan adopted, numerous experiments were made, which promised satisfactory results. This promise was unfulfilled on the larger scale, and as a consequence, £120,000 is said to have been expended on the launch before the ship floated. The estimated cost was only £14,000. When launched, the total weight to be moved was 12,000 tons—about twice as great a weight as has ever been launched in any other vessel.

It has been estimated that no less than thirty thousand iron plates and three millions of rivets were used in building the ship! The contracts for hull and engines were made in 1853; the first attempt to launch was made in November, 1857; the ship floated on the 31st of January, 1858, and started on her first cruise in September, 1859, her completion having been delayed by the financial embarrassments of the company. She has been afloat, therefore, for twenty years; and as no dock can accommodate her, repairs or cleaning of the bottom can only be accomplished by grounding her on a gridiron, as described at page 22. Yet even with this exceptional treatment, the iron hull has proved exceedingly durable; and although for three years past the ship has lain in Milford Haven, her rest has not been the result of incapacity for further service, but the lack of suitable employment. Her period of greatest usefulness and success was from 1865 to 1875, when she was engaged in laying submarine telegraph cables; but work of that kind is, of course, exceptional, and although the *Great Eastern* did it admirably, smaller vessels specially built for the work can now perform it satisfactorily and at less expense. It is not easy to foresee what the future of the great ship will be; but it is interesting to note that there is a prospect of her being better cared for than in the past. In connection with the docks now in process of construction at Milford, a dry dock is being built sufficiently large to accommodate her; and when it is completed she will have in reserve facilities for cleaning and repairs never enjoyed before. This century is not likely to witness the construction of another *Great Eastern*, and it is to be hoped that she may long be preserved, even if she cannot be profitably employed; for she thoroughly deserves the praise accorded to her by one who was always opposed to her construction—"She is a marvellous piece of workmanship; . . . a triumph of mechanical skill."

INDUSTRIAL LEGISLATION.—V.

LORD ASHLEY ACCEPTS THE PARLIAMENTARY LEADERSHIP OF THE SHORT-TIME MOVEMENT—GREAT MEETING IN THE LONDON TAVERN—COMMISSION OF INQUIRY.

By James Henderson, one of H.M. Assistant-Inspectors of Factories.

SADLER'S defeat at the general election of 1832 was regarded for a time as a great discouragement to those interested in the movement for limiting the hours of work in factories. The agitation, however, had now taken such a hold upon the country that it had long ceased to depend upon the exertions and energy of any single individual.

The new Parliament, moreover, contained many tried friends of the cause of the factory children. Mr. Joseph Brotherton, who had laboured side by side with the first Sir Robert Peel, was elected for Salford, and Mr. John Fielden and Mr. William Cobbett, both of whom had distinguished themselves by their public advocacy of a ten-hours Bill, were returned for Oldham. But by far the most valuable ally which the cause had yet secured was gained when Lord Ashley (the present Lord Shaftesbury) consented to champion the cause of the oppressed children in the reformed House of Commons. The idea of enlisting this nobleman in the work appears to have originated at a delegate meeting at which representatives were present from the various short-time committees then existing in Lancashire and Yorkshire. The Rev. G. S. Bull, a tried friend of the cause, was commissioned to go to London to confer with its friends there, as to the appointment of a new Parliamentary leader; and in the course of a very short time Mr. Bull was enabled to send a circular to the different short-time committees, informing them that Lord Ashley had assented to take up Mr. Sadler's Bill and make the measure his own. In accordance with this determination, his lordship at once gave notice that he would re-introduce

The "Great Eastern" paying out the Atlantic Cable.

Mr. Sadler's Bill on the 5th of March, 1833. From this date onward to the present time Lord Shaftesbury has been more intimately associated with factory legislation than any other man; and as we traverse the history of the subject we shall find his name most prominently and most continuously connected with every effort made in this direction to improve the moral and social condition of the operative classes. A more desirable leader for a movement of this kind could not possibly have been obtained, and the wisdom of the selection made by the leaders of the short-time movement was soon manifested. When he consented to the Rev. Mr. Bull's proposal, Lord Ashley assured him that so long as he was supported in his efforts by the operatives themselves, he would never flinch from the work; and right nobly did his lordship fulfil this pledge during the twenty years of earnest, untiring, and indefatigable labour which followed while he was engaged heart and soul in a cause which he practically came to make his own.

The evidence taken by the Select Committee during the previous session, and over which Mr. Sadler presided, had exercised a considerable influence on public opinion by this time, and the manufacturers themselves were aroused to the knowledge of the fact that some practical steps must be taken to restrain the gross abuses which it was clearly proved existed in no small proportion of the factories. An association was formed in London under the patronage of his Royal Highness the Duke of Sussex, which had for its object the improvement of the condition of factory children, and an important meeting of this association was held in the London Tavern on the 23rd of February, 1833, a few days after Lord Ashley had given notice of his intention to re-introduce Mr. Sadler's Bill. The Lord Mayor, Sir Peter Laurie, presided, and it is interesting at this distance of time to recall the names of some of the more eminent men who took part in the proceeding. Among the speakers were—Lord Ashley, the Hon. Wm. Duncombe (Lord Faversham), Rev. G. S. Bull, Mr. O'Connell, M.P., Mr. J. W. Helps, Col. Williams, M.P., Mr. G. Lyall, Mr. Oastler, Mr. H. Pownall, Mr. J. H. Freeze, and Mr. T. Sadler. Among other gentlemen on the platform on this occasion were—Colonel Torrens, M.P., Colonel Williams, M.P., Mr. Robinson, M.P., Mr. Wilks, M.P., Sir Edward Knatchbull, M.P., Sir Andrew Agnew, M.P., Mr. Robert Owen, Mr. Nathaniel Gould, and Mr. Labouchere. All shades of political and religious opinion were represented on this occasion, and the proceedings excited a remarkable amount of interest throughout the country. One of the most interesting of the speeches delivered was that by Mr. Richard Oastler, who stated that in his district in Yorkshire, it was a common thing for children of seven years of age to be compelled to work for eighteen and in some cases even for twenty hours out of the twenty-four. They were unable to exist under such labour, and the churchyards proved that this was the case. Such children, moreover, were frequently beaten with a heavy strap until breast and back were black. One little child, Mr. Oastler stated, he had himself seen, who, although under ten years of age, had been most unmercifully beaten for having, when tired out, spoiled a piece of yarn of some three inches in length. The evidence given before Mr. Sadler's committee more than corroborated the strongest statements made by those who desired to promote some restriction on the hours of work. The report, in fact, so teems with facts of this kind that it is difficult to make a selection. One witness—a clothier from Scholes, near Holmfirth, who stated that he had many opportunities of observing the treatment which children received in the woollen factories in his neighbourhood—on being asked a question upon this point, said, speaking of the children, "They are generally cruelly treated—so cruelly treated that they dared not hardly for their lives be too late at work in a morning. When I have been at the mills in the winter season, when the children are at work in the evening, the very first thing they inquire is, 'What o'clock is it?' if I should answer, 'Seven,' they say, 'Only seven! it is a great while to ten; but we must not give up till ten or past.'" This witness went on to say that his heart was ready to bleed for them when he saw them so fatigued that they were in such a state of apathy and insensibility as hardly to know what they were doing. Under these circumstances, they frequently made errors in their work, and for this they were most shamefully punished, being generally beaten with the "billy roller"—a heavy rod of iron from two to three feet long. This witness testified that he had seen the billy spinners take this dangerous weapon and rap the little children on the heads till they made them crack so that the blow might be heard some distance off above the noise and din of the machinery. In some cases serious injuries were inflicted, which ultimately resulted in loss of life. Another witness, an operative, stated that when a boy he had been beaten with a billy roller, when drowsy after sixteen or seventeen hours of

continuous labour, until he had repeatedly vomited blood. A volume, indeed, might be filled with extracts from the evidence taken by this Committee, as to the shameful cruelties practised upon the young children employed in factories. Ill-fed, over-worked, and cruelly beaten, they were indeed fit objects of pity and compassion. Regarded from our present stand-point of view, it must be a subject of wonder and surprise to all who have read the shocking details laid before this Select Committee that those who sought to have this state of things amended by legislation should have had any difficulty whatever. Were such a tale of misery and woe laid before a Select Committee of the present day, the whole country would be up in arms at once to demand an immediate remedy. Nothing, perhaps, could more forcibly illustrate the contrast between the social condition of the people now and what it was some half a century ago than the fact that the disclosures made before Mr. Sadler's Select Committee should have excited so little interest and so little sympathy for the miserable victims of human avarice and cupidity. But the firm and decided attitude taken in the House of Commons by Lord Ashley, and the influence exercised by the influential association which had been established to promote a short-time Bill, were not without effect, and the more reasonable among the employers in the textile manufactures became convinced of the necessity of something being done to remedy the grievances of the factory children. In their interest, Lord Morpeth gave notice of the introduction of a rival Bill, for limiting the hours of work. The operatives interested in the short-time movement dreaded nothing so much as a compromise, and Lord Morpeth's movement was consequently very unpopular among them.

Both proposals for immediate legislation, however, were set aside for a time by a suggestion for the appointment of a Royal Commission, to collect information in the manufacturing districts with respect to the employment of children in factories, and to devise the best means for the curtailment of their labours. A motion to this effect was formally made in the House of Commons by Mr. Wilson Patten (now Lord Winmarleigh) on the 3rd of April, 1833. Lord Morpeth also supported this motion, on the ground that the agreement between Mr. Sadler and the opponents of his Bill in the previous session had not yet been fulfilled. It was arranged that Mr. Sadler should first call his evidence, and endeavour to prove his case, and then that his opponents should follow with theirs. The inquiry, however, had come to an abrupt conclusion, and before the latter had had this opportunity. Both Mr. Patten and Lord Morpeth earnestly disclaimed any desire to delay legislation, and there was certainly some show of reason in their arguments in favour of having the case of the opponents of the Bill thoroughly considered. The leaders of the short-time movement, however, were bitterly opposed to the appointment of a Commission of Inquiry, which they regarded simply as an excuse for delay. When the motion came on for discussion, Lord Ashley opposed it most strenuously, and although it was supported by the Government, he only failed to defeat it by one vote, the numbers on the division being 74 in favour of the appointment of the Commission, and 73 against it. The narrowness of this division no doubt had its influence with the Government. The commission was issued within little more than a fortnight after this division—on the 19th of April; and the gentlemen named in it to conduct the proposed inquiry were:—Francis Bisset Hawkins, Thomas Southwood Smith, Sir David Barry, Thomas Tooke, Leonard Horner, John Elliot Drinkwater, Robert Mackintosh, James Stuart, John Wilsford Cowell, Edward Carleton Tufnell, Alfred Power, Edwin Chadwick, Stephen Woolriche, John Spencer, and Charles Lowdon. Mr. John Wilson was appointed Secretary to the Commission. As there was a general desire that the question should be dealt with if possible during the currency of the session of 1833, the expedition with which the Commissioners got through their work may be judged of by the fact that the first report they presented was dated the 25th of June. They collected an immense amount of information, and although their labours were regarded with much jealousy and dissatisfaction by the factory operatives and their friends, yet they unquestionably contributed in a large degree to the formation of that public opinion which was expressed subsequently in the Acts of the Legislature. In some towns in the North, the opposition offered to the Commissioners was absurd and unreasonable. Formal protests against their proceedings were lodged with them at Manchester and Leeds. Mr. Richard Oastler absolutely refused to recognise the Commission when it reached the latter town, and declined to afford the members of it in their official capacity the slightest aid or assistance. Notwithstanding these discouragements, the work of the Commission appears to have been faithfully and

conscientiously performed. Of course, the evidence submitted to them was very contradictory at times, but that the operatives had no cause for the want of confidence they displayed in the Commission, was made manifest when the reports were issued. The first, as we have just remarked, was presented to Parliament before the end of June, and was signed by Mr. Thomas Tooke, Mr. Edwin Chadwick, and Mr. Southwood Smith. The chief conclusions they arrived at, were thus summed up:—

"1st. That the children employed in all the principal branches of manufacture throughout the kingdom, work during the same number of hours as the adults.

"2nd. That the effects of labour during such hours, are in a great number of cases permanent deterioration of the physical constitution, the production of disease wholly irremediable, and the partial or entire exclusion (by reason of excessive fatigue) from the means of obtaining adequate education and acquiring useful habits, or of profiting by those means when afforded.

"3rd. That at the age when children suffer these injuries from the labour they undergo, they are not free agents, but are let out to hire, the wages they earn being received and appropriated by their parents and guardians.

"We are therefore of opinion that a case is made out for the interference of the Legislature, in behalf of the children employed in factories."

HEMP, FLAX, AND JUTE.—VIII.

KENDREW AND PORTHOUSE'S FLAX-SPINNING MACHINES—DRAWING.

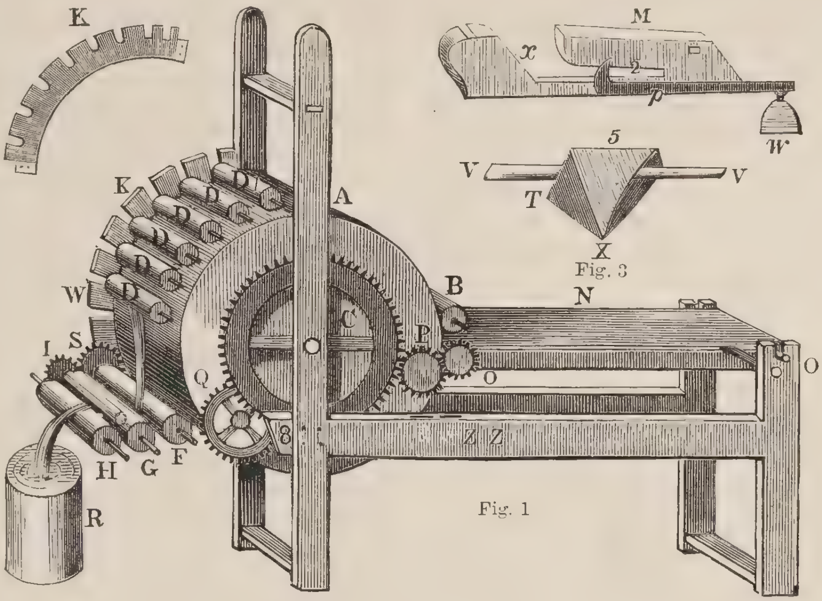
By David Bremner, Author of "The Industries of Scotland."

THE invention of Kendrew and Porthouse exercised such an important influence on the linen manufacture, not only of this country, but of all Europe, that it deserves more than the passing notice already accorded to it; and we reproduce the specification, with its accompanying drawings, as they appeared in "The Repertory of Arts and Manufactures," published in the year 1802:—

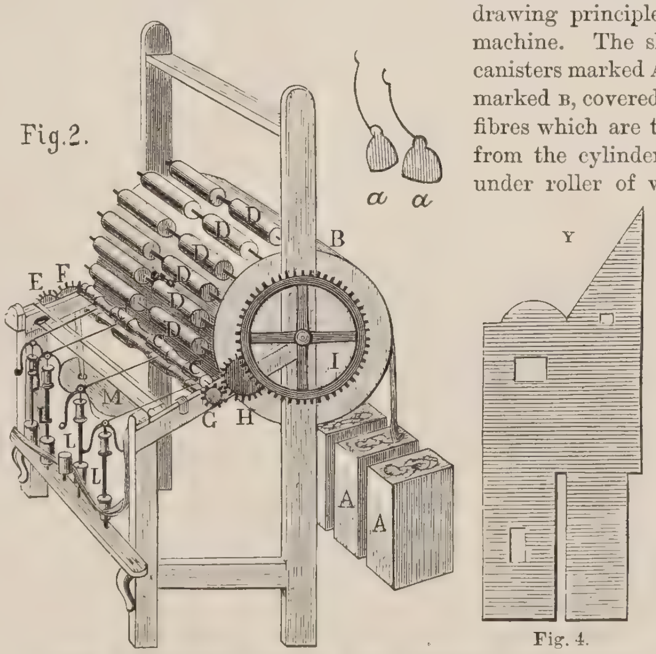
> "Specification of the patent granted to Mr. John Kendrew of Darlington, in the county of Durham, optic glass-grinder, and Mr. Thomas Porthouse of the same place, clockmaker, for a new mill or machine, upon new principles, for spinning yarn from hemp, tow, flax, or wool.
>
> "Dated June 19, 1787.

"To all of whom these presents shall come, &c. Now know ye, that in compliance with the said proviso, they the said John Kendrew and John Porthouse do hereby describe and ascertain the nature of the said invention, and in what manner the same is to be performed, as follows; that is to say: The machine may be worked or used by a water-mill, horse-mill, or any other kind of mill, and is made and used as hereafter described in the two drawings or plans added hereto, and figured 1 and 2, and severally marked. There is a cylinder marked A in the drawing Fig. 1, three feet diameter and ten inches broad, made of dry wood or metal, turned true, and covered on its circumference with a smooth leather, upon which are placed the rollers marked D, covered with leather, and supported in their situations by the slits in the curved piece of wood marked K, in which the iron axis of the rollers turn, but suffer them to press on the wheel marked A. There must be another piece similar to the above to support the other end of the rollers. These rollers are of different weights. The upper roller, marked D 1, is two stone, the rest decreasing, to the least, which is only two pounds weight and one half. There is an iron fluted roller marked F, furnished with a toothed wheel at each end, and a wood one marked G, covered with cloth, and over it a smooth leather. There is an assisting roller, marked H, of fluted iron. These rollers are supported by their axis, turning in the slit marked 2 of the piece of wood marked M (Fig. 3), which is here separated from the end of the frame marked 8, to show the rollers which work. The rollers marked G and F are squeezed together by means of the lever marked P, and its weight, marked *w* (Fig. 3). The roller marked H is pressed to that marked G by its axis acting upon the inclined plane marked X (Fig. 3). There is a rubbing roller covered with woollen cloth, and on its axis is a small wheel, marked I, driven by the wheel marked S. This roller rests upon the roller marked G, and by its motion prevents any dirt or fibres from adhering to it. There is a cloth, N, revolving over two rollers marked O O, which has motion given to it from the wheel marked C by means of another wheel marked P. This cloth moves at the same pace as the surface of the wheel marked A. There is a supporter, marked Y (Fig. 4), of the axis of the wheels marked O P, but is removed, in order to show them; it is fixed by its mortices in the tenons marked Z Z. The roller marked B is kept in action by its endeavour to slip down the inclined plane at the top of the piece marked Y, thereby pressing against the revolving cylinder; and another piece, similar to this, must be understood to support the other end of the roller's axis. By the side of this revolving cloth is a table placed, of the same length and breadth as the cloth is, to which belong two smooth cloths or leathers, of the same size as the table. The machine being thus prepared, the attendant or workman must take a quantity of hemp, tow, flax, or wool, more or

less, according to the fineness of the thread to be made, and lay or spread it evenly upon one of the smooth cloths on the table, then place it on the revolving cloth marked N, motion being communicated to the roller marked F by wheelwork, as used from a water, horse, or other kind of mill, which wheelwork is communicated to the wheel marked Q, on whose axis is a nut, which turns the wheel marked C; and thereby the cylinder marked A moves, and with it all the rollers, by which motion the hemp, tow, flax, or wool, is drawn forward. The cloth turns down, but the hemp, tow, flax, or wool, go upon the cylinder marked A, under the roller marked B, and so forward under all the rollers marked D, then falls in between the rollers marked G F, turns under the roller marked G, and over the roller marked H, which, as it gives the rollers hold on the hemp, tow, flax, or wool in two places, enables them to drag forward the long fibres thereof, though many of them are to draw from under the 4th and 5th of the pressing cylinders marked D; it then falls into the canister marked R, and as both wheelwork and rollers marked F G H move three times faster than the cloth and cylinder, the sliver must be three times longer than when presented. By the time this is drawing, the other cloth is filled with hemp, tow, flax, or wool, as before, and laid upon the revolving rollers, and laying the end of the flax, tow, hemp, or wool, over the end of the other, which goes forward as before, and thus the continued sliver is produced so long as the machine is in motion. But in order that this sliver may come out of the canister marked R without entanglement, it must pass through an instrument marked 5 (Fig. 3), placed over the rollers marked F G, its open side marked T to the cylinder supported by its ends, marked V V, in the slits marked W of the before-described piece marked K. The aperture marked X is so small as to press the fibres close to each



DIAGRAMS ILLUSTRATING KENDREW AND PORTHOUSE'S SPECIFICATION.



DIAGRAMS ILLUSTRATING KENDREW AND PORTHOUSE'S SPECIFICATION.

other on their passage through it to their passing the rollers, by which means they remain pressed side by side in the sliver, and will not entangle. These thick slivers are drawn smaller by similar processes, and in the same manner as used for cotton, but the machines for drawing are all of the same structure as the above, except that they have no revolving cloth. The sliver is held to the cylinder under the roller marked B, which draws it forward under all the rollers as before described, drawing it out or lengthening it over various machines through which it passes till it be small enough for the spinning machine. It must be remarked that the cylinders are made less in diameter according to the different smallness of the sliver intended to be drawn upon them at the first.

"The foregoing several letters or marks are in the machine figured 1. The spinning machine (Fig. 2), as to its drawing principle, is the same as the drawing machine. The slivers are presented to it in canisters marked A, and drawn over the cylinder marked B, covered with rollers marked D. The fibres which are to form the thread are drawn from the cylinder by the rollers marked C, the under roller of which is made of fluted iron, the others of wood, covered with leather. They move six or eight times faster than the cylinder marked B; are enabled to draw the hemp, tow, flax, or wool, forward from under the pressing rollers marked D by being squeezed together by the weights and clocks marked *a a* hooked to the small part of the rollers marked C. There is a belt of smooth cloth marked E, moving on two rollers, which are turned by the wheel marked F, on the axis of the fluted roller, at the opposite end of which, at the mark G, is a nut, which turns the wheel marked H, on whose axis is another nut turning the wheel marked I, and thereby the cylinder marked B, with all its rollers. These rollers move in curved pieces of wood or metal, marked K, which, to prevent confusion, are not represented in their places. They have slits in them, in which the rollers' axes are guided, but so deep as at all

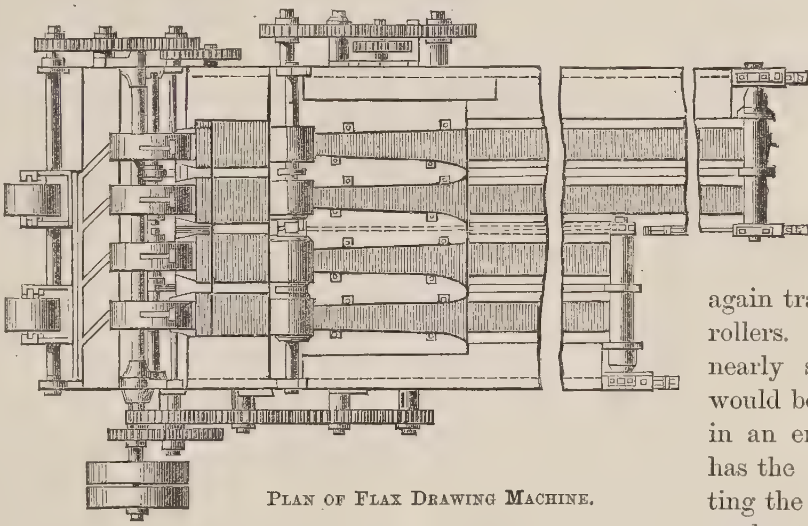
times to suffer the rollers to press upon the cylinder. These rollers are covered with cloth and leather. The top roller is about 10 lb. weight, decreasing to the sixth roller, which is only about 1 lb. weight. The yarn is turned by the spindles marked L, and rubbed over the wet cloth belt, if spinning linen yarn, but if spinning worsted yarn the belt must be removed, that it may not touch it as it passes to the spool, which it coils round as fast as the rollers let it out. The spindles marked L are turned by a belt from the wheel marked M, which derives its motion from the mill, and by a wheel on its axis communicates it to the roller marked C, by the wheel marked F, and so to the rest, as above described. The hemp, tow, flax, or wool, is twined in the same manner as in cotton mills.

"In witness whereof, &c."

Having secured their invention by a patent, Messrs. Kendrew and Porthouse at once proceeded to turn it to account, and with this view had a set of machines erected in a small building on the bank of the Skerne, at Darlington, which Kendrew occupied as a shop for grinding glass. Though neither had much, if any, knowledge of spinning, they succeeded so far as to attract the attention of several persons engaged in the linen manufacture, who, having satisfied themselves that the machines were capable of producing yarn more expeditiously than it could be done by hand spinning, obtained licenses to use the machines. Among the first in the field was Mr. John Marshall, of Leeds, the founder of what has long been one of the largest linen factories in the world. In company with two partners, Mr. Marshall erected a mill, which was fitted with Kendrew and Porthouse's machines. This was in 1788; and the mill, which was on what would now be considered an exceedingly small scale, was driven by water power. The concern did not realise the expectations of the firm; and Mr. Marshall, who had a clear knowledge as to what was requisite for the success of machine spinning, applied himself to improving the machines. The progress he made encouraged the firm to further enterprise; and in 1791 a new mill, having a floor space of 1,000 square yards, was built at Holbeck, Leeds. In this case the machinery was also driven by a water wheel, supplied by an atmospheric engine. This arrangement was common in those days; and one looks back with wonder to a time when the steam engine had no higher task assigned to it than to pump water from a low to a high level, in order that it might be poured upon and give motion to a bucketed wheel. There was anything but economy in making the steam do its work in this roundabout way. Mr. Marshall's first partners left him in 1793, at which time he had 900 spindles running at a satisfactory rate of profit. It is believed, in fact, that this was the first really profitable flax-spinning mill in the kingdom. Two years later, Mr. Marshall erected in the same locality a mill having 2,500 square yards of floor, besides warehouses and other buildings. This enterprise must have met with remarkable encouragement, for in 1797 Mr. Marshall and his partners built at Shrewsbury a large mill, fireproof throughout, which is still in the occupation of Messrs. Marshall and Co. In subsequent years the extensive establishments owned by the firm at Leeds were erected. Mr. Marshall's example was followed by manufacturers in various parts of England and Scotland, and as the machines came under the notice of persons of superior mechanical skill, they were gradually improved. Mr. James Aytoun, of Kirkcaldy, contributed largely to this work. He had been sent to Manchester to acquire a knowledge of cotton spinning, and while there heard of the invention of the flax-spinning machine. Shrewdly guessing that a fresh field of enterprise, in which he might usefully engage, was about to be opened up by the invention, he proceeded to Darlington, and applied himself to studying the machines. He was not long there when the knowledge of cotton machinery which he possessed enabled him to suggest various improvements. Having accomplished the object of his visit, Mr. Aytoun obtained a license to work four spinning frames of thirty-six spindles each, and with this he returned to his native country, and established a factory at Kinghorn, where he had a long and prosperous career as a flax spinner. Kendrew and Porthouse, after working in partnership for a few years, embarked in separate enterprises, the former building a mill at Houghton, and the latter acquiring a similar property at Cockham, both in the vicinity of Darlington. Porthouse, we are told, was a quiet, retired man, and left the management of the mill chiefly to his wife, who was an able, active woman. She attended the work daily, from morning till night, going about with tools in hand, shifting pinions, and doing other little and necessary pieces of work as an ordinary manager would.

A good idea of the form of the earliest flax-spinning machines and their mode of operations, may be derived from the specifications and drawings; how they have been improved upon will be learnt from the following description of the machines and processes now used in flax mills. From the hackling room the flax passes to the spreading, or first drawing machine, which consists of an endless feed apron, which conducts the flax to a pair of holding

rollers, where it is combed, and gradually drawn forward, by a series of travelling combs of peculiar construction, to two sets of drawing rollers, which elongate the sliver, and pass it on to the delivery rollers, whence it drops into a can. The apron is divided longitudinally into four sections, corresponding with the number of slivers to be formed. On each of these divisions the attendants of the machine place the flax in an even layer, one end of each bundle overlaying the other to the extent of three-fourths of its length. As the flax is drawn along on the apron, it is seized by the first pair of rollers, which, moving at a slower rate than the other parts of the machine, hold the flax, as it were, and only give it off gradually. In front of the holding-rollers are the combs, which travel in a plane, and, disentangling the fibres and bringing them into parallel order, carry them forward to the drawing rollers. The combs are the most important part of the machine, and in their highest development display very considerable ingenuity.



Plan of Flax Drawing Machine.

It is desirable that the flax should be subjected to the action of the comb at the nearest possible point to the holding rollers, so that the draw may take effect while the fibres are firmly retained in the grasp of the rollers, and to meet this requirement a variety of modes have been invented. One of the earliest of these was the chain-gill, in which the combs were attached at either extremity to an endless chain. This was followed by the screw-gill, which, after undergoing various modifications, may now be pronounced perfect. In this machine the combs are made to travel by the action upon their extremities of shafts furnished with a screw-thread. On reaching a point near the drawing rollers the combs drop in succession to a lower level, where they are received on a second pair of screw shafts and carried back to the holding rollers. Here they are raised by a pair of cams to the higher level, are at once brought to bear on the flax, and again travel to the drawing rollers. Their motion is nearly similar to what it would be if they were fixed in an endless chain, but it has the advantage of admitting the combs to begin their work at the closest possible point to the holding rollers. This ingenious contrivance is the invention of Messrs. P. Fairbairn and Co., Leeds, who have devoted much attention to the improvement of flax-working machines. In order to bring the fibres into fit condition for spinning, the slivers formed on the spreading machine are passed through the drawing machine several times. This machine is similar to the spreader in every respect, except that it is fed with slivers instead of loose flax. Usually eight slivers are put through at a time, and elongated until they are reduced to the size which one of them presented originally. After the last drawing the slivers are fed into the roving machine, by which they are twisted into a soft cord, and made ready for the final operation of spinning.

IRON AND STEEL.—IX.

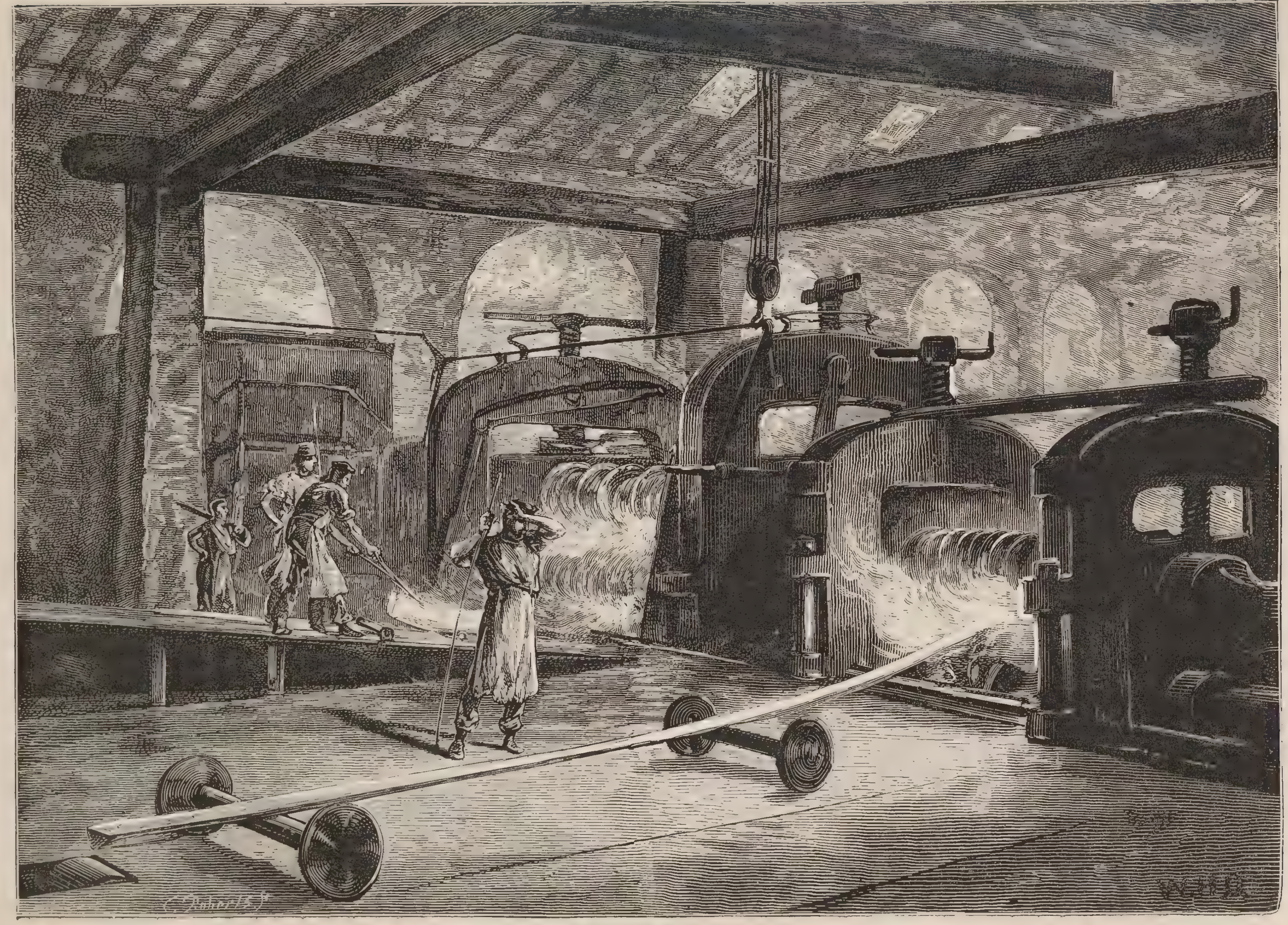
CEMENTATION—CAST STEEL.

By William Dundas Scott-Moncrieff, C.E.

HITHERTO we have spoken of the treatment of iron in its relation to carbon, either by the blast furnace or the Bessemer process; but there is another method of altering its character known as cementation, which is so interesting that we must devote a short space to a description of it. This process seems to have been unknown to the ancients, and first acquired a scientific and commercial

importance in the early part of the last century, when it was much talked of as a wonderful discovery for converting bad iron into good. A number of adventurers, who became possessed of what they professed to be a great secret, made all sorts of proposals to capitalists by which they were to make fortunes as if they had discovered a new El Dorado, and even brought their projects under the notice of the French Court, which led to much discussion at the time. It seems to have been the unscientific manner in which the process was spoken of, and the unscrupulous character of the men who professed to understand it at this period, that led to a full inquiry having been made, in which Réaumur, the famous French philosopher, took a conspicuous part. In spite, however, of the attention which was given to the subject at that time, and the interest that has been attached to it ever since, on the part of the leading men of science in Europe, cementation still remains nearly as great a puzzle as ever. Although we are well acquainted with every detail of the process, we are still unable to say how it is that certain effects follow from their apparent causes. One of the most honest investigators who ever wrote upon this subject—Gay-Lussac—in criticising the views of certain persons who had come to rash conclusions, states that he sees no reason to suppose that the process of cementation is altogether inexplicable, but at the same time he seems to be unable to explain it by any theory consistent with the state of knowledge at the time. Dr. Percy, whose authority we have so often had occasion to quote, was a pupil of Gay-Lussac, and bears testimony to the value of his master's views; but though he himself made a long series of experiments, he was unable to arrive at any conclusion that pointed clearly to the way in which iron that has previously been deprived of its carbon becomes impregnated during cementation. Briefly described, the process is as follows:—Bars of wrought iron, upon the quality of which the value of the steel altogether depends, are packed together in a kind of retort, or brick chamber, so that the whole of their surfaces are in contact with charcoal. They are then subjected to a high temperature for several days, during which great experience and care are necessary, both in the regulation of the heat and the period of its continuance. After being allowed to cool slowly, the bars are withdrawn, and are then found to be covered over with blisters not unlike those produced upon the hands by rowing; and at the same time the iron has been converted into what is known as "blister-steel." The difficulty that exists in the scientific explanation of the process, arises from our ignorance of the manner in which the carbon becomes impregnated through the solid iron, as it never reaches the temperature of melting, and all the theories about the carbon being in a gaseous state quite fail to explain the puzzle. The ancients laid down a general proposition in physics which they accepted as a universal aphorism—that no substance in nature could act upon another substance unless they were dissolved or reduced to the fluid or gaseous state; but the process of cementation affords an instance of two solid bodies acting through their solid condition. Gay-Lussac, in summing up his remarks upon the process, says that we have no reason to suppose that the ancient proposition is true, but that all we can affirm is, that the solid state of matter is the one which is least capable of undergoing any change in its constitution.

After the "blister" steel has been removed from the charcoal, it is cut into small pieces, and hammered very much in the same way as the scraps that we have already had occasion to speak of when describing the forge. When it has been drawn out again into bars, it is called "shear" steel, and when it has been again subjected to another course of treatment in contact with charcoal, and re-hammered, it is called "double-shear" steel. It was in this way that nearly all the steel used for the manufactures of Sheffield goods was manufactured, till within the last fifty years, when another process was discovered. The product of this method is known as cast steel; and there is, perhaps, no department of the iron trade that has led to a greater amount of invention, or that forms the subject of a larger number of patents. It was no sooner known that by melting fine Swedish wrought iron or "blister" steel in a crucible, and adding carbon while the contents were in a state of fusion, a finer quality of steel might be obtained, than almost every manufacturer, however ignorant, thought himself justified in patenting some particular mixture, or some insignificant detail. The first inventor of the cast steel process seems to have been Benjamin Huntsman, who was born in 1704. He was a clock-maker of Doncaster, and retained the secret of the manufacture until it was discovered by a knave who disguised himself as a beggar, and found a night's shelter in the casting house. As the process was conducted very much by rule of thumb, and as the most skilful workmen, who were best able to connect the appearances of the metal in a state of fusion with the quality of the material produced, had an advantage over all theorists who were



Rolling Steel Rails.

unacquainted with the practical working of the melting-pot, every master believed himself to be able to produce better steel than any one else. It followed from this that the steel manufacture of Sheffield ceased altogether to be connected with the well-known advances which have been made in the science of metallurgy, and still remains to a great extent in the hands of empirics who have never depended upon any more reliable foundation for their business than the skill of a few highly-paid workmen. But although the steel manufacturers of Sheffield eagerly grasped at the new method, they refused to recognise the claims of another unfortunate inventor, and formed one of the most scandalous combinations that ever existed to ruin the fortunes of the man to whom they were solely indebted for the discovery. The famous litigation which arose out of the patents of Heath, the inventor of the process for producing cast steel with manganese, is one of those instances—fortunately few—in which the judgment of the Supreme Court of Appeal in this country is open in its scientific aspect to the gravest criticism. It afforded opportunities for at least one learned and famous judge to prove the truth of the proverb that in science, as in other things, a little knowledge is a dangerous thing, and the only reasonable conclusion to be arrived at now is, that if the scientific knowledge of the Bench had been sounder, its decision would have been different, and that one of the most deserving inventors that ever made this country his debtor would have obtained a well-merited reward. It is not easy to convey to the mind of the general reader any very clear idea of the issue involved in this famous law-suit, but, briefly stated, it may be put in this way :—While Heath discovered that by adding a mixture of carbon and manganese, which may be called carburet of manganese, to "blister" steel or Swedish iron while in a state of fusion, fine cast steel could be produced, he patented the preparation as it was before being thrown into the crucible. It was discovered by another steel maker that the same result was obtained by adding the substances separately to the molten contents, and it was upon this that the combination was formed for the purpose of opposing Heath's claim. It appears, however, that the only possible way of accounting for the similar results that follow either from first mixing the substances or putting them separately in the melting-pot is, that the same combination occurs in both cases, and that therefore any value that Heath's patent may have had was equally applicable to either method. The analysis of molten metal is, however, somewhat beyond the capacity of even the most skilful experimentalists, and so a presumption, which never really existed, was introduced with the effect of throwing out the unfortunate inventor altogether. Within a short period of the discovery of Heath's method, various modifications of the substances to be added to the molten charge were proposed; but his discovery is the only one that has remained of permanent value.

As the dimensions of the apparatus necessary for producing cast steel are regulated more or less by the size of the ingots which are cast and hammered, and as these are generally small, a cast-steel work does not imply any very extensive application of machinery. The crucibles in which the "blister" steel, or Swedish iron, is melted, are generally about 9 inches in diameter across the mouth, and about 18 inches in height. They are made in moulds of some refractory material—such as plumbago, which is capable of resisting a very intense heat—and require great care in dressing, as any cracks are, of course, fatal to their usefulness. The furnaces consist of square chambers sunk below the level of the floor of the casting house, and are placed round a tall chimney, with which they communicate. Each of these chambers is capable of containing one or two crucibles, and is provided with fire-bars at the bottom. The crucible is filled with small pieces of iron and steel that have been previously weighed; and great importance is attached to the proportions of the different kinds of material, as it is believed that an equally good quality of steel may be produced from an inferior charge if the proper "mixture" is made. This is not likely to be the case, however, as any of the deleterious substances, such as sulphur or phosphorus, which exist in bad iron, are probably never got rid of in the melting-pot. This is so far carried out by a saying of the trade, that if the "devil goes into the pot, he is sure to come out again." When the crucible is placed in the furnace or chamber already referred to, it is packed round with coke, the combustion of which soon raises the heat sufficiently to melt the charge. From time to time the lid of the furnace, which is on the level of the floor of the casting house, is removed for the purpose of inspecting the melting contents of the crucible, and also for the purpose of adding fuel. The workman whose office it is to attend to the casting of the ingots, is generally possessed of more than ordinary skill and experience, from the fact that the appearance which the melted contents of

the crucibles present during the process of "converting," is the only means of judging of the proper time to add the carbon and manganese, or to remove the pot from the furnace altogether. This last operation is performed by means of a peculiar-shaped pair of tongs, with which the crucible is clasped. While held in this way, the melted contents are poured into a cast-iron chamber, not unlike a large and elongated bullet mould. As soon as its contents are sufficiently cooled, the mould, which is formed in halves, is removed, and the ingot is then ready for further treatment. This consists only of being heated and hammered. An open hearth, not unlike a blacksmith's, but inclosed as much as possible by coverings of sheet iron, to protect the workmen from the heat, is the apparatus ordinarily employed for heating the ingots to a temperature that renders them capable of being drawn out under the blows of the steam hammer. It is this drawing process that taxes the skill of the workman more than any other operation with which the writer is acquainted. The ingots require to be drawn out into bars of various lengths and of different sections, according to the purposes to which they are to be afterwards applied. The most common shapes are round, oval, square, octagonal, flat, and flattened oval. It is, of course, necessary that the bars should be perfectly symmetrical, and some idea may be formed of the amount of skill and practice which are necessary for producing them, from the fact of their being produced solely from the blows of the hammer; and although an assistant stands ready with a gauge to enable the hammerman to know when the proper diameter of the bar has been reached, still all the fairness and finish are due to the correctness of his eye and the dexterity of his hands. To enable the bar to be passed rapidly backwards and forwards under the blows of the hammer, the hammerman is provided with a seat suspended from the roof, with which he can swing himself rapidly to and fro, with his feet just touching the ground, and being, in this way, able to sway himself speedily backwards and forwards, all the irregularities are gradually eliminated.

In the old days, before the introduction of the steam hammer, the drawing out of steel bars was performed principally by water power acting upon the helve hammers, which have already been described in a previous chapter. The blows required being so frequent, a modification of the ordinary steam hammer was soon introduced, for the benefit of this particular industry. It consisted of making it self-acting, so that when certain valves are adjusted in a particular manner, the steam, acting upon the hammer, causes it to act continuously at any desired number of strokes per minute, and with any intensity that may be required from time to time, according to the nature of the work. In this way the attendant, instead of moving a lever at each blow of the hammer, simply adjusts the self-acting mechanism at the signal of the hammerman; and in finishing a bar of cast steel, when the lustre of surface peculiar to this process is brought out, the hammer is vibrating at as much as two hundred strokes per minute, and falling so lightly as not to produce the slightest mark or flaw. For square bars nothing is needed but a smooth anvil; but for round or octagonal bars, blocks are used that give the necessary form.

It would be impossible to give anything like a full list of the purposes to which cast steel is applied, as they include the whole range of every article that comes under the head of cutlery, not to speak of the tools of nearly every trade or handicraft in the civilised world. For the inferior sorts there is an immense demand in masons' tools, which wear out very rapidly under the constant blows of the mallet; and also for the larger tools required by quarrymen, in the shape of picks and "jumpers" or pointed rods with which holes are drilled in rocks for the introduction of gunpowder or dynamite. The picks, for the most part, are made of iron pointed with steel—generally "blister" steel, obtained from the process of cementation, as it is more capable of being welded to iron than cast steel; though there is one description of the latter, known as "welding cast," which is best of all. In granite quarries immense quantities of steel are used, as the hardness of the material soon wears out even the best tools; and there are no men better judges of the practical merits of good steel than the smiths whose constant labour it is to keep the tools of a large granite quarry in repair.

By some causes that are by no means easily accounted for, the manufacture of cast steel and blister steel is almost entirely confined to Sheffield. This, no doubt, arose at one time from the secret manner in which it was conducted, as all who were anxious to get information naturally went to the only town where it could be obtained; but even now it seems to be the natural home of the industry. In Scotland, where the iron trade has become so extensive, till within the last few years there was only one small steel work in existence, and that was worked by water power only. Since then

the partners of the old concern have become connected with two other establishments, both very favourably situated; but neither of them give any promise of being able to establish a footing that will ever compete with the importations of Sheffield in respect to quantity.

At present good cast steel is the most expensive of all forms of iron, that which is used for engineers' tools costing from £60 to £70 per ton. This arises from the high quality of the material necessary for manufacturing it, which is almost invariably Swedish charcoal iron, and also from the laborious manner in which the bars require to be hammered. It is, however, just within the range of possibility that improved methods may lead to its becoming much cheaper; and there is none that would affect the cost more materially than the process of rolling, which has done so much in other departments, and which forms the subject of our illustration.

WOOL AND WORSTED.—VIII.

CARPETS AND HEARTHRUGS.

By William Gibson.

STUDENTS and antiquaries differ widely from the general run of men as to the objects and places round which centre veneration and affection. To the former the etymology of a word, an aged ruin, or the mark upon a piece of faded china, opens vast vistas of visionary verbiage, whereas the latter don't care who built the Great Pyramid, and sleep none the less soundly though they are unable to decide between disputants round an Etruscan vase, as to the true reading of some queer hieroglyphic. The word "carpet" would mount the memory of the former on the fleet wings of fancy, and the wondering listener would hear gorgeous descriptions of the palaces of the Pharaohs, the temples of Heliopolis, the interiors of Babylon, the royal residence at Shushan, the castles of India, the harems of Moslem kaliphs, the palatial homes of the aristocracy of Greece, or the artistic decorations on wall and floor of the houses of the patricians of Rome. They would tell how the Egyptian priesthood had their sacred rugs to adorn the *sacraria* of their marvellous god-houses; how the proud rulers of that ancient land trod on "velvet pile" of ingenious and cunning work; how in the palaces of Babylon the guests of despotic sovereigns lounged upon rich carpets, and walked over priceless works of textile art; how the great men in the times of blind Homer laid down spotless wool-work on their rich marble floors; how that thoughtless spendthrift Iphicrates, as Ptolemy Philadelphus informs us, at one of his most lavish banquets, underneath two hundred golden couches "strewed purple carpets of the finest wool with patterns on both sides, laid handsomely broidered rugs of the same material, enriched with beautifully elaborated figures, over daïs, stool, and table; and covered the centre of the floors, where the guests sauntered with beauty hanging on their arm, with thin Persian mats, having upon them accurate representations of men, animals, and fabulous monsters, cunningly worked by nimble fingers." They would wax eloquent on the glories of Tyrian and Sardinian dyes that shimmered "beneath the ivory-footed couches purple cushioned," referred to by Plautus, and the rarest learning and profoundest research would be exhausted in order to convince the listener that in art, deftness, and genius, these so-called rude and primitive men were our superiors in almost all branches of architectural design, and decorative furniture. But all that would be worse than Greek to the matter-of-fact Englishman, and he might turn upon such rhapsodies and declare that to him the prosaic factory, built of red brick, standing in one of our Lancashire towns, and sending out annually thousands of yards of "Brussels," erring at once against all laws of taste and design, was dearer to him than "the cloud-capped towers and gorgeous palaces" of far-off times, because in that commonplace building had laboured a man whose name is loved or respected by every Briton—honest John Bright, "the People's Tribune."

Our Saxon forefathers were content to strew their floors with sweet rushes (*Acorus calamus*), and down to the time of the seventh Harry little other covering was popular. There were exceptions, however, made in respect of presence chambers of kings, private rooms of nobles, and the sanctum of the abbot. These were covered at first with carpets made first of all by long thongs of leather interlaced, and then by pieces of cloth treated in

the same way. In one of the most valuable MSS. in the British Museum—Sir John Lydgate's Life of St. Edmund, profusely illustrated with coloured drawings—we find the bed-room of the saint covered with a checkered carpet of green and black—like a chess-board; and a hearthrug of Gothic design, in gold and black, before the roaring wood fire. As this vellum book was written in the fourteenth century, we know that carpets were already in use; but it was the Moors who introduced the Oriental floor coverings into Western Europe, and the Belgians and French that popularised the excellent imitations of scarce and costly Indian and Persian work. Henry VIII. tried to naturalise the tapestry manufacture in England, but failed. His successor, the first James, had a flourishing factory at Mortlake; but it was not till 1750, when the Duke of Cumberland's concern at Paddington was in full swing, that the carpet industry of this kingdom had its birth. But carpet weavers have taken very long strides indeed since the brown Egyptian, the tawny Babylonian, or the Indian workman erected his loom between two adjacent trees, and through weary months, and, even years, perseveringly knotted tuft after tuft of coloured wools on the perpendicular warp threads of his primitive machine till the finished carpet stood forth a marvel of design and a thing of beauty. Axminster, Kidderminster, and other places took carpets in hand last century, and faithfully copied Eastern designs; but now Halifax, Rochdale, Edinburgh, Kilmarnock, and Glasgow, by the aid of the Jacquard and other looms, and by Whytock's and Templeton's patents, have thrown those early endeavours completely in the shade. From being a luxury of the wealthy and great, carpets have become a necessity to all, and there are few cottage houses whose best room cannot now boast a bit of "tapestry," "Kidderminster," "Brussels," or more homely "drugget."

Jacquard revolutionised a good many textile industries by his ingenious loom. Silk, velvet, woollen, carpet, linen, cotton, muslin, and other manufacturers, owe much to him; and Mr. Bigelow, of America, by the introduction of his power looms—though the original patent has been much improved since—wrought a still more wonderful transformation in this and other lands. Without these, carpets and a good many other things might be enviously regarded by the industrious poor, but never possessed; and it is to these and other inventors that so many thousands of the labouring classes are indebted for the means of daily earning an honest livelihood.

The Jacquard loom long held undisputed sway at Wilton, Kidderminster, and elsewhere, and on it were woven the double, treble, fourfold, and even "six-frame Brussels," or the cheaper but no less durable "Kidderminster." The word "carpet," philologists tell us, comes from the Italian *carpetta* or perhaps from the Dutch *karpet*; and certainly the best and earliest makers in Western Europe, both of carpets and tapestries, came from the flat strip of land along the eastern shore of the North Sea known as "the Low Countries."

"Brussels" carpet was first made at Wilton, where it was introduced from Tournai, in Belgium, rather more than a century and a quarter ago, and it has always held its own in public esteem. It was woven on Jacquard looms, and consists of one to six thicknesses of woollen thread wrought on a hemp or other strong back. Two, three, four, or five thicknesses, however, are most general, and these usually indicate the number of colours used in forming the pattern. A "six-frame" carpet requires considerable space for the machinery necessary to its production, and the aim of the manufacturer has ever been to give his fabrics the appearance of more "frames" than are actually used. The "frames" are, as their name indicates, appliances for holding the bobbins or reels of wool of different colours for the "warp." Each "frame" is placed horizontally behind the loom, and filled with reels of the same colours, so that, where six hues are used, and each comes out in the pattern with equal frequency, six frames are, or rather were, necessary. Each reel of the frame contributes one warp thread to the carpet, and as there are 260 threads as a rule in one width of 27 inches, no less than 1,560 bobbins would be required in a full "six-frame" carpet. But in actual working this is not necessary. For example, in most carpets of the Brussels sort there may not be more than four full frames required, other colours occurring but rarely in the pattern; and in that case four frames and a half only will be required, or five at the outside. Every fraction of a frame dispensed with in the weaving is a saving to the manufacturer; and even to the expert there is often difficulty in telling how many have actually been employed. The carpet looks the same, and will in all likelihood fetch the same price, as one to produce which six full frames were needful.

Patterns in linen, cotton, wool, or flax, are all got in the same way. First of all the designer draws his pattern, in the colours which the finished product is intended to assume, on paper

divided into minute squares, such as may be seen in the windows of any Berlin wool shop for slippers, cushion covers, watch pockets, tidies, or tea cosies. When the drawing is completed, it is handed over to "stampers," an occupation usually confined to young women. These are provided with pieces of cardboard, about 14 inches long and 3 broad, and, with the pattern before them, they "stamp" or cut, at equal distances, along the lines drawn horizontally on the "cards," small holes for every coloured square in the first line on the design. Following line by line the whole pattern, they stamp holes until the cards, which are numbered, are punctured according to the notion of the artist. The cards are then sewn together in order so as to form a flexible chain, and are ready for "mounting."

"Putters-on"—*i.e.*, skilled workmen who prepare the warp for the loom—now get the pattern and cut it into a number of longitudinal stripes, each strip of squares from top to bottom of the design representing one thread in the warp; consequently, the designs have each 260 squares in the width from side to side. Each warp thread, too, represents one stitch in the woven web. Now let us suppose that in the pattern there are four alternating colours, with two others—red and yellow—occurring only occasionally in the pattern. The chief colours will need four full frames, and the others may be managed by a quarter of a frame each, and that will be a four and a half frame carpet, which a good artist will make look like a full-size six frame. The putter-on takes the first strip of his pattern, and from the frame draws through the "mails" the colour indicated on it chiefly, and so on with each strip till he has exhausted the 260 and arrived at the opposite selvage. The "mails" are bits of lead three or four inches long and the thickness of stout wire, attached to cords which are connected with the "machine." At a position in these cords level with the beam of the loom are small brass or copper "eyes," through which the putter-on draws the threads and passes them through the corresponding "eyes" in the "heddles" or "leaves," and so through the reeds attached to the "lathe," when they are fixed to the "beam" in front. In the old days the hand-loom weaver sat with his breast to this beam, and beneath him were a set of "treddles" communicating with the "heddles," and which, when he pressed them down, elevated or depressed a section of the 260 threads in the warp, so as to allow the shuttle to pass in between. The "Jacquard machine" is an apparatus fixed to looms by which the warp threads in the web are raised as required to form the pattern. This is done by a series of hooked wires, and a revolving perforated drum against one side of which the prepared cards are pressed. Wherever there is a hole in the card, the wire opposite it is allowed to pass into the drum. Where there are no holes in the card, the wires that press against it are pushed back, the hooked bars disengaged, and the threads in the warp attached to these remain unelevated. Row after row is thus treated at each depression of a treddle, till the whole of the cards are exhausted, and one complete pattern has been formed in the web. They are then reversed, and the process begins *de novo*. The operation is repeated "pick" after "pick," as stitches are called, till the whole pattern is completed, when the "cards" are returned to their original position, and the pattern is woven again and again till the whole of the weft is exhausted, or the necessary length of cloth is obtained. Great care, it will be seen, is necessary both in "stamping" and "putting-on," for if the girls in one instance punch a hole where they should not, or if the workman draws a wrong coloured thread through the "mails," the pattern will be spoiled, as the "machine" is infallible, and only raises threads indicated by holes in the "cards." Consequently a trial pattern is generally woven when the loom is "mounted" or prepared, and errors rectified before the actual operation of weaving is set about in earnest. Practice, however, in this as in other things, makes perfect, and there is seldom any necessity for disturbing a web after it has once been mounted.

Such is the essential working of the Jacquard loom for all kinds of fabrics; but "Brussels" carpet consists of a series of looped stitches (see Fig. 1). For weaving "Brussels," a series of wires is necessary. As soon as the requisite "warp threads" have been raised by the "machine," so as to leave space between the rest of the warp and those selected to form pattern stitches across the cloth, one of these wires is pushed through, the shuttle follows with a thread of weft, and the lathe

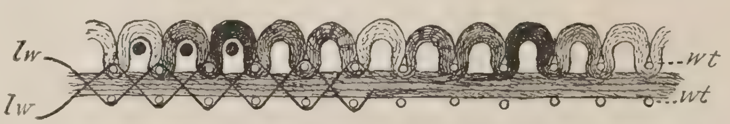
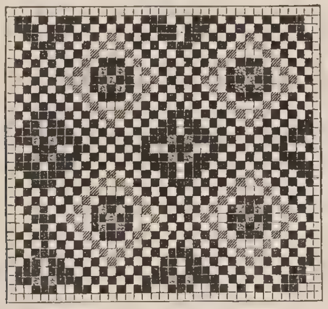
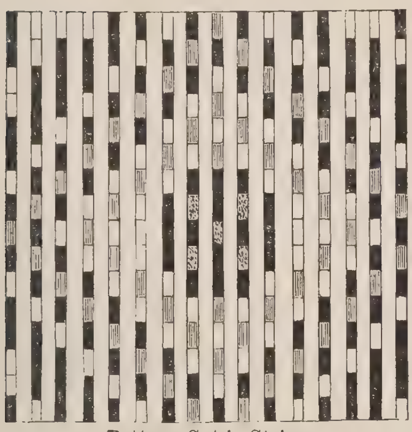


Fig. 1.—SECTION OF "BRUSSELS."
wt is the Weft-thread; *lw* shows how it is fastened by the Warp.

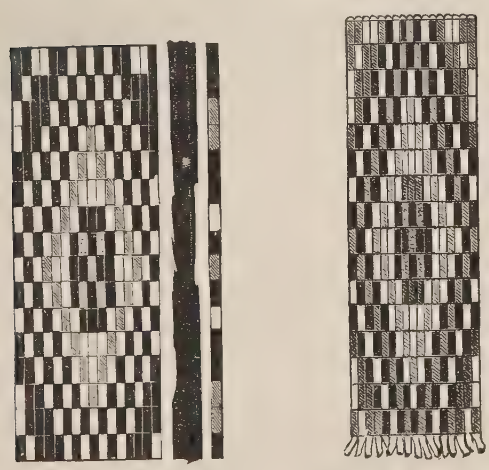
is pressed tightly against the previous row of stitches. In actual weaving ten or a dozen rows of "wires" are left in the cloth, so that no loop may be disturbed while the next is being formed, and



Pattern as Designed.



Pattern Cut in Strips.



Pattern in Fac-simile. Warp Dyed to Pattern.

Fig. 2.—Pattern in Various Stages.

then, beginning with the first inserted, they are withdrawn one after another as new wires are woven in.

As the demand for Brussels increased, and the necessity for cheapening carpets consequently arose, manufacturers were driven to expedients in order to produce simulations of the genuine article that would look equally well, be more rapidly woven, and produced at much less cost. Inventive genius came to their aid, and very soon the problem was solved. We have said that in "frame" wrought carpets the reels in each frame were of the same colour, and an ingenious individual asked why the carpet could not be woven white, and by the aid of blocks have the pattern impressed on it afterwards. This was tried, and with considerable success; indeed, the Messrs. Bright, of Rochdale, we believe, turn out much of this class of carpet, which is generally known as "tapestry Brussels," or tapestry. It has the insuperable disadvantage, however, which no amount of skill has yet been able to obviate, of presenting, when finished, a more or less blurred character. This is caused by the dye of one stitch running into the other, especially if the one be of a dark and the other of a lighter colour.

Another inventor suggested that the "warp" should be dyed before it was woven, and though this was an improvement upon the process just referred to, it had also its drawbacks. For every new pattern new blocks were necessary, and in course of time by the repetition of one pattern the old blocks wore out; and the same blurred effect was generally the result after the web was woven, notwithstanding the care taken to insure success. The circumference of the wires in use being known, the length of warp thread required to make a stitch is computable to an almost infinitesimal fraction. Design paper ruled in accordance with these calculations is procured, and the pattern painted in the usual way. Here, instead of squares (see Fig. 2), the spaces are parallelograms or oblongs. Cut into strips, it is at once apparent where stitches of one colour or another would have to be printed on the warp; and blocks prepared for the purpose are used, and each thread of pattern dyed in patches according to the design. By this means the "putting-on" was rendered simple, and the cards and other gear largely done away with; but the cost of the blocks was still an item of expense, and there was some difficulty in getting each stitch to rise exactly over the top of the wire. It was reserved for Mr. Whytock, a well-known carpet weaver of Edinburgh, to relieve anxious manufacturers from their difficulty, by a contrivance which he patented, and which is now generally in use. His great aim was to print the warp, and yet do away with the blocks. He managed it by constructing a huge drum (see Fig. 3) of such a circumference that 6, 8, 12, or 16 hanks of yarn wound upon it would cover it with a layer, just like a big bobbin with one layer of

thread. Underneath the drum, and travelling across the face of it, he laid down a set of rails

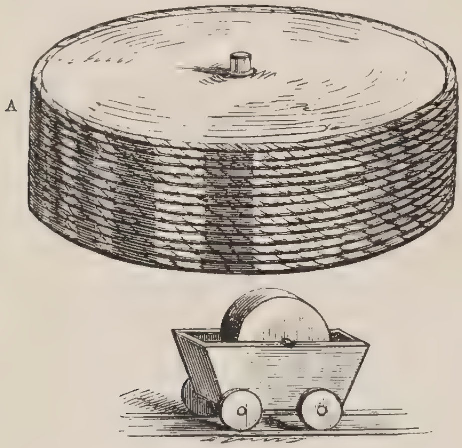


Fig. 3.—Whytock's Drum (a) and Trough (b).

an inch or two apart, and on this placed troughs partially filled with different dyes, and having each a felt roller running in sockets, so as to be half in and half out of the colour. The trough, its wheels, and rollers, when passed under the drum almost touched it. Now he wound his yarn on the cylinder, took the strip of pattern answering to the first warp thread, and fixed it to a segment of the drum, so that he might see what colours required to be transferred to the yarn. Causing the huge drum to revolve till the first stitch was just over the rails, he pushed the trough along, and the colour roller, broad enough to mark one, two, or three stitches as required, marked the yarn in its passage. By an apparatus the cylinder turned so as to bring the next oblong stitch over the rails, and the trough of that colour was run under as before, till the whole yarn on it was dyed exactly as the strip of design. The same operation was repeated with all the threads till the pattern was complete.

The yarn is steamed to make the dye enter the pores of the wool, but the necessity for doing this causes the colours to "run" less or more. The steamed thread is then wound round a hot cylinder, handed to the "setter on," warped, and mounted on the loom. The Crossleys, of Halifax, are the chief producers of this class of goods, though many thousands of yards are turned out annually in Kidderminster, Lancashire, and different parts of Scotland.

"Kidderminster," or "Scotch carpet," as it is sometimes called, was originally manufactured in the town from which it derives its name; but now it is chiefly made in Yorkshire, Durham, and Scotland. These are either "single," "double," or "three-ply" textures. Mr. Thomas Morton, of Kilmarnock, was the man who gave an impetus to this class of manufacture, by devising appliances for improving the quality of the goods. In order to strengthen the material itself, and at the same time to introduce a greater variety of colour, he used three warp webs instead of two. The Kidderminster has a plain figured surface, and the pattern appears on both sides, lighter above and darker beneath. The same machinery used in weaving Brussels is brought into play for the making of Kidderminster, except the wires, for the surface is not "looped," but plain.

"Wilton," or velvet-pile carpets, are all made on the tapestry principle, the only difference being that, as the wires are thicker, the pattern squares are more oblong, and the length of warp is consequently increased. The wires used for "Wiltons" are not round, as those employed by such a firm as that in Halifax for "tapestry," but are flattened along one side. This flat part of the wires has to be kept at the top of the loop, and when ten or a dozen "picks" have been accomplished, a knife passes along and cuts the loop in two. This forms the pile, which is combed up and shorn, so as to present a uniform surface, by a machine very similar to that used in the cloth factories (see Fig. 4).

"Axminsters" are really "Wiltons," but in these

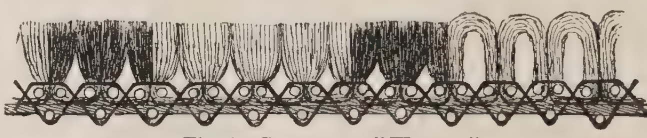


Fig. 4.—Section of "Wilton."
Part of Loops cut and shorn; three uncut.

the method of weaving is very different. The patent "Axminster" is much dearer than the ordinary Wilton, because for the most part hand woven, and this is the only kind of carpet that can be made so as exactly to fit various shaped rooms, without destroying the unity of design. It is in every respect a nearer relative of the true Oriental than any other carpet produced in Europe. We owe it to the ingenuity of Mr. James Templeton, of Glasgow, who patented his process in 1839. This process produces hearthrugs, chair covers, couch covers, carpets for oblong, square, three-cornered, bizarre-shaped rooms, for cabins of ships, altar steps, church *sacraria*, &c., of the most gorgeous and beautiful designs in all the colours of the rainbow, in Persian, Indian, Greek, and Roman patterns, from the hands of such masters of decorative art as Parrie, Owen Jones, Digby Wyatt, and others.

Templeton's patent, like the majority of great

inventions, is very simple in theory and adaptable in practice. Instead of dyeing the warp, he weaves the pattern in the weft in such a way that the most delicate shades and combinations of colours, as well as the most intricate patterns, can be produced; and, when finished, are as sharp in outline and as perfect in *ensemble* as the design when it left the studio of the decorator. The designs are prepared in the usual way on paper ruled into squares, as in Brussels work (see Fig. 5). These designs

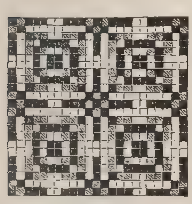


Fig. 5.—Design of Templeton's.

are then cut across the squares from selvage to selvage, instead of lengthways, as in the case of the Brussels manufacture. The strips are then fastened together right and left alternately, so as to form a continuous ribbon. Alternately we say :—Thus, the right-hand side of the second row of squares is attached at the right of the first, the left of the third to the left of the second, the right of the fourth to the right of the third, the left of the fifth to the left of the fourth, and so on with the whole pattern (see Fig. 6).

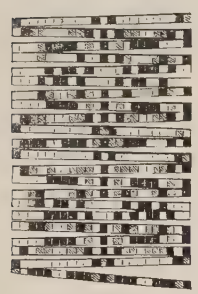


Fig. 6.—Design of Templeton's Cut and Joined for Weaving.

They are now handed to a female weaver, who has a warp, sets of four threads being close together, and such a space between each set that, when the material woven is cut lengthways (see Figs. 7 and 8), a kind of woollen "rush" — as milliners would say — is formed, firmly woven at the centre. She then takes the first strip and the first stitch in that strip, which we shall suppose to be green, and with a green shuttle weaves three or four rows, so as to get the thickness of pile required.

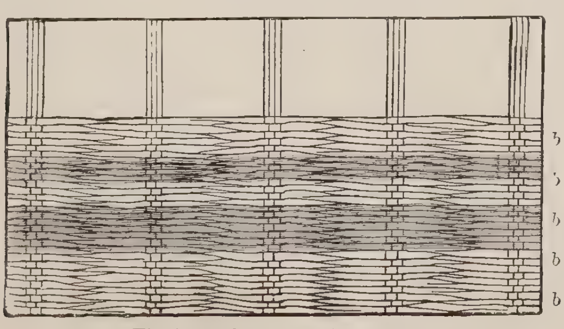


Fig. 7.—"Chenille" in Web.
(*a*) Warp Threads; (*b*) Coloured Weft woven in.

Then the next square, which may be some other colour, and so on with each square till she reaches

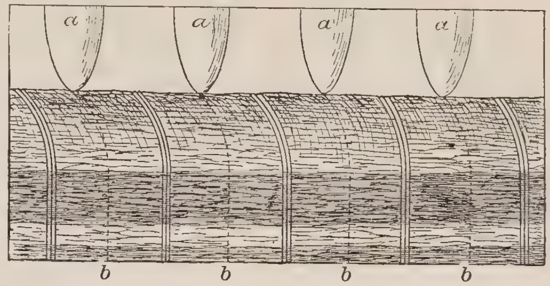


Fig. 8.—Cutting the "Chenille" Web.
(*a*) The Knives; (*b*) Direction in which they cut the "Chenille."

the end of the first width. These strips are called "chenille" (see Fig. 9), and, after being cut, they are wound upon spools, care being taken to bring the two sides of the chenille together into one "pile." As many of these chenilles as are required for a

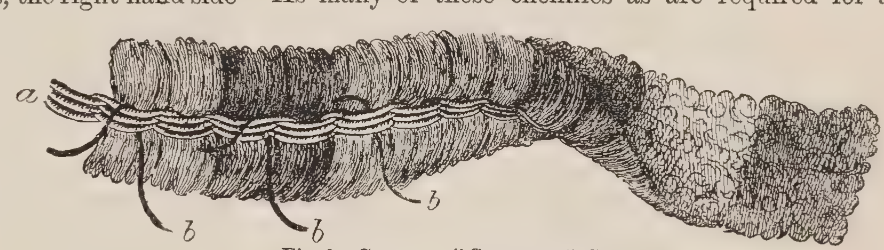


Fig. 9.—Strip of "Chenille" Cut.
(*a*) The Warp to which it is woven; (*b*) the Weft which binds it in its place.

complete carpet are woven, spooled, and handed over to the weaver, who has only to pass them backwards and forwards between the warp threads, follow each chenille by a "pick" of the same mate-

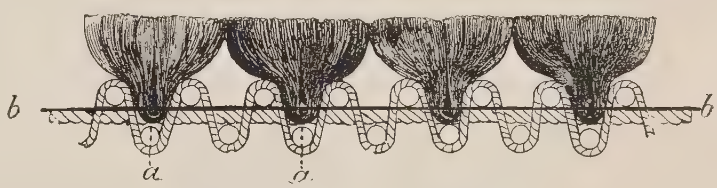


Fig. 10.—Section of "Axminster."
(*a*) The Weft Threads; (*b*) the Warp.

rial as the warp to keep the row in its place, and fasten it, and the perfect pattern will be produced (see Fig. 10). Care, of course, has to be taken that each selvage is exactly placed, that the pile is properly combed up over the warp threads, and that each row of chenille is woven evenly into its place. Nor are these things so easy as they appear, for sometimes carpets are woven many yards wide, and on looms so broad that two, four, six, and even eight men are required to work abreast at the same beam, in order that there may be no flaws in the pattern or inequalities in the weaving. The warp in these looms, and the weft used to fasten each "chenille" as it is placed across the width of the

web, may be of hemp, strong woollen yarn, or any other material. When a certain portion of the carpet has been woven, the weaver, if there be only one, as in the case of most hearthrugs, or weavers, if there be more, shear the pile with great care to get evenness of surface; and when pressed, brushed, and finished, the production is rich, velvety, and yielding to the tread as the most costly fabrications of Turkey.

These are the chief classes of carpet produced in Great Britain, though there are, of course, others. "Druggets" are well enough known, and so simple in their construction as not to need any lengthened description. These are generally of a striped pattern of various colours, which of course are formed in the warp by the "setter-on." The weft is always, or nearly always, a neutral, or darker colour than the warp, and they are woven on an ordinary double-"heddle" Bigelow steam loom. Sometimes checks are produced, and in these warp and weft of the same colours are used, the weaver judging by a tape measure when to change the "shuttle." Felted carpets, very cheap, and printed after "felting," are common. Mattings of coir from the cocoa-nut fibre, Manilla hemp (*Musa textilis*) and Indian mat grass (*Cyperus textilis*) are woven in Dundee and other parts of the kingdom, and in prisons and convict establishments, and may be called carpets, but need not trouble us here.

Steam looms were not employed much in the carpet trade before 1850, if at all; but when it is said that, whereas a hand weaver could not produce more than 5 or 7 yards of carpet on the longest day in June by the closest application, and that the machines will turn out as much as 35, 40, or even 50 yards a day, their value will be apparent. It is difficult to get at the quantity of wool specially devoted to carpets, or the number of yards produced in the year, because of course the great bulk is consumed at home; but we may form some conception of the magnitude of the trade by considering the number of yards we annually export. In 1871, according to the official return, the number of yards of carpet produced in the United Kingdom and exported was 10,957,453, valued at £1,648,411. In 1872 it had risen to 11,815,900 yards, valued at £1,916,774; but in 1873 there was a falling off, the numbers being 9,921,100 yards, valued at £1,597,383. There was still a further decline in 1874, the quantity exported being 9,208,271 yards, valued at £1,480,892. The year 1875 showed a great reduction, for during the twelve months only 7,522,660 yards were exported, the value being £1,159,979. We may, in all likelihood, double these figures to get at the total produce, and it is possible that the apparent decline in the amount manufactured since 1871 may be accounted for by the fact that the kinds of carpet which we used to export are being produced elsewhere, or that the home consumption of native fabrics is more than it used to be. At any rate, whatever the reason, we are not from the figures quoted above to conclude that the industry is waning, for the contrary is the fact.

EMINENT MANUFACTURERS.—IV.

SIR JOHN BROWN, OF SHEFFIELD.

By Robert Haig Dunbar.

SHEFFIELD, the Steelopolis of England, and the hardware capital of the world, owes a very large share of its greatness to the industrial genius of Sir John Brown, whose career is one of the most remarkable in the records of our country's commerce. He was the "father," if the term may be used, of the railway material trade, from the conical buffer to steel rails, tyres, and axles. He introduced the iron trade into South Yorkshire; and, passing over half a hundred other works, he was the originator of rolled armour plates, which he perfected until in these times the mighty war-ships which ride our seas are clothed with iron from 8 to 22 inches thick. To him, more than to any other man, is due the revolution which has taken place in the navies of the world, since the French ship *La Gloire*, with its plating of 4½ inches, disturbed the repose of the English Admiralty, up till now, when the Italian Government built the *Duilio* and *Dandolo*, each armoured with 22-inch plates, and armed with 100-ton guns. The story of a life which has led to such results must be worth telling.

Sir John Brown is a Sheffielder by birth, having first seen the light in the year 1816, in a part of the town which was then occupied by families of good position, and known as "Favell's Yard,"

situate in Fargate. When he had "half turned" 13, he left school, and in 1830 was apprenticed to the firm of Earl, Horton, and Co., who were factors in Orchard Place. He still retains his indenture at Endcliffe Hall, cherishing it as one of his most precious possessions. In the course of a few years, the firm went into the steel trade. About 1836 they removed to Rockingham Street, where their establishment was known as the Hallamshire Works. In addition to the steel trade, they commenced the manufacture of files and table cutlery. The apprentice very soon stepped to the front. When he became of age, in 1838, Mr. Earl, who was the senior partner, paid his *employé* the high compliment of asking him to enter the establishment as a partner. Owing to lack of the necessary capital, the young man was unable to do so; and Mr. Earl, who took a kindly and appreciative interest in his welfare, then offered him his factoring business, and at the same time most liberally volunteered to join in finding the money to carry it on. John Brown's father and uncle guaranteed £500 to a local bank, and this modest credit was the start in life of one whose career has been a remarkable example of what can be done by diligence, thrift, foresight, and perseverance. For several years he was a cutler—the fact will be new even to the great majority of Sheffield readers. Cutlery, however, did not attract him so much as files and steel. Courteous and considerate, even in these younger days, he first sought the consent of the employer who had befriended him. That consent was readily obtained, and he commenced the manufacture of steel on his own account in Orchard Street. He afterwards removed to Furnival Street, where we find him energetically engaged in the production of steel, files, and railway springs, having previously disposed of his factoring business to the firm of H. G. Long and Co. When in Furnival Street, in 1848, he invented the conical steel buffer spring, which he patented. That proved, as local manufacturers say, "a good thing." At that time there was no external buffer in use upon the railway lines, and for wagons there was no buffer at all. John Brown's were the first, and the importance of the invention was so promptly discovered, that in a short time he was turning them out of his works at the rate of 150 sets a week. It may be interesting now to state—what has never been previously mentioned in print—that the first pair of conical buffers ever made were sent to South Wales, having been ordered by the Taff Valley Railway; the second to Scotland, for the Glasgow and South-Western Railway; and the third to Ireland, for the Dublin and Drogheda Company. The first English line on which they were used was the London and North-Western. The business extended so rapidly after this that we find him producing railway springs and buffers in Upper Furnival Street, erecting additional spring shops in Hereford Street, other spring shops in Backfields, and converting furnaces in Holly Street. To a practical mind like his, the importance of concentrating his operations in one locality speedily became obvious. An opportunity of accomplishing this purpose occurred in 1864. In Saville Street had been erected the Queen's Works. The site covered an area of three acres, of which less than one acre was built upon. These works were purchased, re-christened the Atlas Works, and rapidly extended. By this change he was able to gather all his departments into one place, where he could personally superintend his rapidly-increasing business. Up to that time the district had been a sylvan retreat; and Sir John can yet recall with pleasure the blue-bells which used to flourish in the woods opposite to his counting-house windows. At the present day, Saville Street, though not a bleak and howling wilderness, is black with smoke-begrimed buildings and tall chimneys, belching forth their sooty volumes, which obscure both sun and sky.

When the Atlas Works were fairly set going, it occurred to their owner that the demand for iron in the district was sufficient to justify his adding the manufacture of the raw material. He then commenced the production of iron for steel-making purposes, which was the introduction of the iron industry into the Sheffield district. Sir John Brown, in addition to introducing the railway buffer and spring trade to the town, was thus also the father of the iron trade in the locality. The result of his enterprise was to make Sheffield practically independent of Sweden or any other country from which a large amount of iron for manufacturing purposes used to be drawn.

The original works becoming too small to produce what was required to meet the demand, the works on the south side of the Midland Railway were commenced. Here, ten converting furnaces were erected for the purpose of converting the iron to be manufactured into steel for supplying the wants of the town, as well as of the Atlas Works. This was also the beginning of the introduction of iron, of Yorkshire quality, for boilers and bridge plates. By bridge plates are understood such plates as are used on Charing

Cross Bridge, some of which were supplied from the Atlas Works.

Shortly after this, Sir John Brown made his great discovery in thick-rolled armoured plates, which revolutionised the navies of the world, and with which his name will ever be remembered in the Admiralty Board of this and other empires. He was in the habit of taking a run on the Continent in the autumn. In 1860, on his return, he came by way of Toulon, where, as accident would have it, the French ship *La Gloire* put into the harbour. *La Gloire* was a timber-built 90-gun three-decker, cut down into "an exaggerated corvette," with 40 big guns and hammered-plate armour $4\frac{1}{2}$ inches thick, 5 feet long, and 2 feet wide. Our Admiralty were a little scared by the French Government putting *La Gloire* in commission, for no fewer than ten 90-gun and 100-gun timber-built ships were stopped in their progress, in order to be cut down and plated like the French vessel. The owner of the Atlas Works had too shrewd a head not to make the most of his meeting with *La Gloire.* He was not allowed on board, but examined the ship most thoroughly, and came to the conclusion that the armour plates used in clothing her could be rolled. The French plates were hammered. Sir John's mind was promptly made up. He was convinced he could roll a plate more reliable, and tenacious, and uniform in quality than it could be hammered. He returned to Sheffield and set to work. In August, 1862, the fame of the Mayor's works—for by this time he had entered the Council and become Chief Citizen of Sheffield—had induced Lord Palmerston, then Premier of England, to visit Sheffield. He was the guest of "Alderman Brown," at his residence, Shirle Hill, was entertained by the Mayor to a magnificent banquet, and inspected his host's works in Saville Street. We refer to this now for purpose of comparison. Lord Palmerston saw rolled a plate 3ft. 9in. wide, 18ft. 6in. long, $5\frac{1}{2}$in. thick, and upwards of 6 tons in weight. The process is described at length in the *Times* of August 11, 1862, and in terms of wonderment at the feat accomplished. In April of the following year the Lords of the Admiralty, headed by the Duke of Somerset, and followed by officials and others, who made up a company of nearly 100, visited Sheffield to witness the opening of a new rolling mill, which the owner of the Atlas Works had put down. This was a great day for John Brown and for Sheffield. He had been able to overcome official repugnance to his new plan of making plates; and, once overcome, their Lordships of the Admiralty had visited him in stately style. They saw several plates rolled, chiefly $4\frac{1}{2}$, $5\frac{3}{8}$, and $5\frac{1}{2}$ inches thick, and 40 feet long; but towards the close of the visit a plate, 12 inches thick, and 15 to 20 feet in length, was rolled in the presence of the official representatives of the British Navy, who then saw for the first time that the splendid promises of their host were faithfully kept. A 5-inch armour plate, upwards of 40 feet long, and 4 feet wide, followed, and when this was finished the Mayor conducted the Duke of Somerset round the rolls to look at the plate. The men cheered as they approached, and the Mayor, pausing for a moment, said to his men, "We are all proud of your exploits; you are worthy of the name of Englishmen. His Grace, the Duke of Somerset, wishes me to express his admiration of what you have done." At a collation given in the dining-room of the works, the Duke of Somerset said that, "Mr. Brown had asked the Admiralty if they would be able to build ships to carry the plates he could make;" and he then went on to say, "We are very glad to come here, and I am sure I have profited and been very much interested by what I have to-day seen. Nothing is more interesting to me than seeing these works, and seeing the men of these works—to see the intelligence, the good temper, and the kindly feeling towards the head of the establishment. It has convinced me that the men themselves are well treated, that they feel they are well treated, and they showed what great kindness and good judgment must be possessed by the head of the establishment. That is the only way in which you can carry on great works like these we have seen to-day. I cannot, therefore, close the observations I have made without asking you to drink the health of Mr. Brown, coupling it with 'Prosperity to the new rolling mill,' for it is the great thing in the proceedings of this day. It is the most striking thing, and will be in the future one of the most wonderful pieces of machinery that have ever been made in this country."

Having thus succeeded, after some difficulty, in disarming opposition at head-quarters, Sir John Brown made rapid progress. In an extremely short period the Atlas Works were known all over the world for their plates, which were not only larger and thicker, but better in quality, than any produced elsewhere. Indeed, no other firm attempted to roll armour plates at that time. He was the first in this country to roll plates of large dimensions, and having secured the lead, he kept it. He laid down machinery to roll plates three times the

length and double the width of any that were then produced. Not satisfied with that, he went on making plates of 9 feet wide, and $6\frac{1}{2}$ inches in thickness. But since that time the trade has so marvellously developed that plates 24 inches thick may be seen at the Atlas Works. At this moment, however, there is no ship in the British Navy which carries so extraordinary an armour, the heaviest being the *Duilio* and the *Dandolo*, Italian iron-clads, which are coated with plates 22 inches thick. The *Inflexible* is said to be partly plated with 22-inch armour. There was something very characteristic of the man in Sir John Brown's enterprise and perseverance in the production of armour plates. In 1862, the Government then in office appeared to have settled down to the conclusion that $4\frac{1}{2}$ inches was the maximum thickness that could be attained. Sir John thought otherwise, and in order to rouse the authorities to more vigorous conceptions of the wants of the British Navy, he wrote what reads now like a kind of challenge to the Government. He offered to produce three plates —of 5 inches, 7 inches, and 8 inches. Sir John's letter stipulated for a certain description of target, and agreed also that if the plates did not resist the ordnance which had penetrated the $4\frac{1}{2}$-inch plates—or the largest ordnance of the day—that he should receive no pay for his experimental plates. The plates were made; they resisted the shot, and the authorities ordered that they should be paid for, and they were paid for in full; and ultimately, as we have seen, the Lords of the Admiralty witnessed for themselves the rolling of a 12-inch armour plate which was no less than 30 feet long.

Sir John Brown has undoubtedly been the great pioneer of this important national manufacture, to which he devoted a large share of his industrial genius, and on which he expended, to insure success, a sum of considerably over £100,000. The Royal Commission on Armour Plates rewarded him by ordering nearly all the plates that they required from his works; and in addition, up to 1863, he had clad in mail fully three-fourths of the whole British Navy. In his trials he had to encounter the fine productions of the Elswick Works, Newcastle-on-Tyne, and the Board of Admiralty were in possession of all the information which could be obtained in reference to foreign experiments. Two steel plates made by M. Krupp had been tested at Antwerp, and each was smashed by the first shot. A steel plate made at Elswick suffered a similar fate in this country; the iron plate made by Brown, and tested at the same time, showed damage only after it had been pounded by thirty-four shots. It is to be regretted, for the sake of the country, that when, in 1878, the question of plates *versus* shots reached a critical stage, Sir John was not to the fore. Whether the plate of the future is to be of layers of iron and steel, or a composite of some other sort, it would be difficult to say; but the remarkable power which brought Sir John to the front in the days when armour plates were in their infancy, we should presume could not have failed to be of service to the State at the juncture alluded to.

Shortly after the Lords of the Admiralty visited Sheffield, the Atlas Works were increased until they extended to an area of over 20 acres, covered with closely-constructed buildings filled with the most

costly and powerful machinery. Every inch of the works was planned by Sir John himself. He had no architect near the place, simply employing a clerk of the works and a couple of draughtsmen, who worked to his instructions. All the machinery was made under his own supervision, and according to his own ideas of strength. When he commenced to make armour plates, he went to the leading machine shops in the country in search of planing and slotting machines sufficiently large to deal with these immense masses. Nothing strong enough could be got. Mr. Shanks, the well-known machine maker of Glasgow, showed him his most powerful productions. Sir John said they were too weak for his work. "You cannot break them," replied Mr. Shanks. "Ah!" said Sir John, "you don't know what I want them for; nothing produced may break them; but I must have them stronger." He then asked Mr. Shanks his price by weight for these machines, and having agreed to pay him a price per ton, called for Mr. Shanks's tracings, took a pencil, strengthened the parts where he thought the tension would be most severe, and then handed the designs back to the maker. When finished, the machines were nearly double the strength of anything then produced, with steel shafts instead of wrought iron introduced into them all.

In the development of the trade, and in the execution of his extensive plans, Sir John was ably assisted by his valuable coadjutors, Mr. J. D. Ellis and Mr. William Bragge. Not long after this, the Atlas Works were giving employment to from 3,000 to 4,000 artisans in the manufacture of armour plates, ordnance forgings, railway bars, steel springs, buffers, tires, axles, &c. Sir John was the first to successfully develop the Bessemer process. When the Institution of Mechanical Engineers visited Sheffield, he was the first to show them the process, the advantages of which were so promptly patent to his shrewd mind, that he lost no time, after the discovery which has done so much to make this the age of steel, in taking out a license from Mr. Bessemer. To Sir John is also due the introduction of steel rails, which are now almost universally adopted on all the leading railways of the world. The first year of his business he turned over about £3,000; the last year the turn-over had increased to nearly £1,000,000. So numerous and varied were the services he rendered to the iron and steel manufactures of Sheffield and South Yorkshire—and, in a large measure, to the manufactures of the country—that the industrial history of the district is indissolubly associated with his name more than with that of any other who has succeeded him.

A thorough Englishman, Sir John Brown kept the benefit of his discoveries for his own country. When his big armour plates began to be noised abroad, foreign Governments applied to him; but Sir John refused to supply any other Power until he had obtained the consent of the Home Government. During the civil war in America, he declined, on this ground, very large orders from the Northern States. The Russian Admiralty were anxious that he should complete orders for them; but Sir John maintained his rule to the last, and, in spite of price and profit, served first the State of which he was so worthy a citizen.

Sir John's industrial career might be followed much further. He was an untiring worker, and great as were his engagements, he realised the truth of the old maxim that it is the busiest man who has the most leisure. He was first in all good works of usefulness and charity. All Saints' Church, Sheffield, which he erected at his own cost—some £12,000—is only one of many works which keep his name green in the memory of Sheffielders. For two years he was Mayor of the borough; he held the high office of Master Cutler for a similar term. He was one of the most liberal of Sheffield's Mayors, and as Master Cutler he entertained his guests with a princely hospitality. He has long been a Borough and County Magistrate, a Town Trustee, and a Church Burgess, and in 1865 he was invested with the authority of a Deputy-Lieutenant of the West Riding. While serving as Mayor in 1863, a requisition, signed by more than one-half of the electors then on the burgess-roll, was presented, asking him to become a candidate for Sheffield at the following election. Sir John accepted the requisition, which was practically presenting him with the representation, but pointed out that a dissolution was not then imminent. Events seem to have interfered with his carrying out the wishes of his townsmen, who, however, even yet look to the kindly owner of Endcliffe Hall as a possible member for Sheffield. In the Volunteer movement, Sir John took a keen interest, raising two companies among his own workpeople, and equipping them at his own cost. He was a large guarantor to the Exhibition of 1862, was President of the jurors in the Iron and Steel Section, and entertained in London and in Sheffield the most distinguished foreign visitors on that occasion. He had awarded to him the gold medal for armour

plates; and at the Paris Exhibition of 1867 he received the sole gold medal for British armour plates by the French jurors. As an employer, Sir John was an example to English manufacturers, both he and his wife being unwearying in their efforts for the social and religious well-being of all in their service. In 1867 her Majesty conferred upon him the honour of knighthood, and in his receiving that distinction Sheffield felt that a special compliment was paid to itself, the day of Sir John and Lady Brown's returning to Sheffield being one of general congratulation and rejoicing.

After many years of successful and honourable labour, Sir John relieved himself of a large portion of the personal burden of his establishment by transferring the business to a limited liability company, of which he remained the chairman, and Mr. J. D. Ellis and Mr. W. Bragge—the two partners he had latterly admitted—the managing directors. The capital of the company was £1,000,000 sterling. For years the concern has been one of the most prosperous in the country; and, though it suffered with others in the depression of 1876–8, the languor was felt to be only one of those fluctuations incident to commerce. For several years, Sir John has been altogether disconnected with the Atlas Works, residing at his noble mansion of Endcliffe Hall, a short distance from the town, yet continuing to take a keen and liberal interest in all questions of local and imperial importance. To education he has ever been a beneficent friend; and it was felt when the School Board was established in Sheffield seven and a half years ago that its most fitting and competent chairman would be Sir John Brown, who has held the position ever since with honour to himself and advantage to his native town. Even in his retirement he is still attached to one branch of the business with which he made his name, being, in conjunction with one or two other gentlemen, the owners of the great iron-ore mountains which overhang Bilbao, in Spain. In that region, a dock and harbour have been constructed, and a railway made, at a cost of £60,000; and there is every hope that the prosperity of the Bilbao Iron Ore Company, long delayed by Carlist troubles and other causes, will soon reward the promoters of an enterprise which has no name among them better known in the world of work than that of Sir John Brown, of Sheffield.

[The portrait of Sir John Brown is taken from a photograph of Mr. E. H. Cox, Torquay.]

COTTON.—IX.

COMBING—DRAWING.

By David Bremner, Author of "The Industries of Scotland."

COTTON intended to be worked into the finer qualities of yarn is now generally combed, instead of being put through the finisher card. The introduction of combing is thus stated by Messrs. Hetherington, of Manchester, in a communication to Mr. Evan Leigh, C.E., the author of a well-known work on "The Science of Modern Cotton Spinning":—"The combing machine is the invention of Mr. Heilmann, of Alsace. It first made its appearance in this country at the International Exhibition of 1851, and shortly afterwards a company was formed in Manchester for the purchase of the patent as applicable to the cotton trade, and for which they paid £30,000. The company consisted of five firms, the most extensive in the trade in the spinning of the finest yarns, and the firm of Messrs. John Hetherington and Sons, of Manchester, were selected as their machine makers. For some time the Patent Combing Company restricted the making of machines to the supply of the members; but after their wants had been provided for, and they had obtained a command of the market, they, on numerous applications from other spinners of fine yarns, consented to supply the trade generally at a price of £500 per machine, £300 of this amount being a charge for royalty. These charges were afterwards modified, and gradually reduced as the term of the patent ran out. The patent was, however, practically extended by the improvements introduced by Messrs. Hetherington, which improvements were embodied in all the machines made subsequently; and the patents for those were purchased from Messrs. Hetherington by the Patent Combing Company. Although the combing machine was at first thought applicable only to the counts of yarn finer than No. 200,

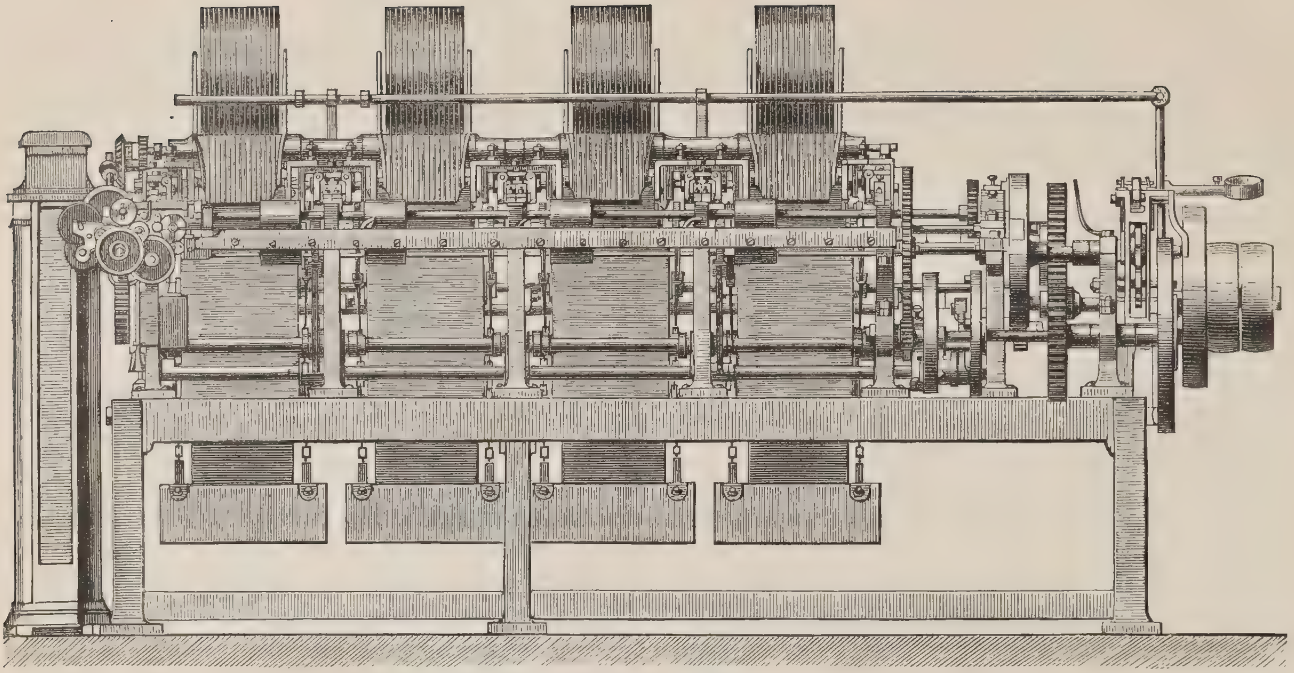


Fig. 1.—Heilmann's Combing Machine.

it was soon found that its range was a much larger one; where quality was an object it became indispensable, and instead of No. 200 being the minimum, this was speedily reduced to No. 120. And it did not stop here, for it has since been found that superior combed single yarn will supersede with advantage the doubled yarn previously used; and this opens another wide field for the use of the combing machine. In the manufacture of sewing thread also, the advantage of yarns made from combed cotton was soon appreciated, so that now Nos. 50, 60, and 80 for such work are combed, as well as some special yarns, Nos. 32 to 40. Some idea of the advantages which have attended the introduction of combing machines can be formed from the fact that there are already (1873) more than 1,600 of them at work, each producing weekly from 120 lb. to 200 lb. of combed cotton, spun principally into the finest counts of yarn."

A general view of the combing machine, as made by Messrs. Hetherington, is given in Fig. 1, and its mode of operation may be seen in Fig. 2, which is a sectional view of the working parts. The machine is fed with a specially-prepared lap, composed of slivers from the carding engine, and the principle of its action is to nip this sliver at certain short intervals, according to the length of the fibre of the cotton being operated upon, and while thus held to comb out the wool. The lap A is first seized by the feeding rollers B and B′, and conducted over the edge of the "cushion plate" D, which is covered with leather. A certain length of the sliver having passed in, the feed motion stops, and the "nipper" C moves towards the cushion plate, pinches the cotton between itself and that plate, and at the same time pushes the plate backward a little way, in order to bring the tuft of cotton into a position to be conveniently operated upon by the combs. The combs, which are usually about twenty in number, increasing in fineness from front to rear, are mounted on a section of the periphery of the cylinder E. The combs which first enter the cotton have thirty teeth to the inch, and the number is gradually increased, until in the case of the last

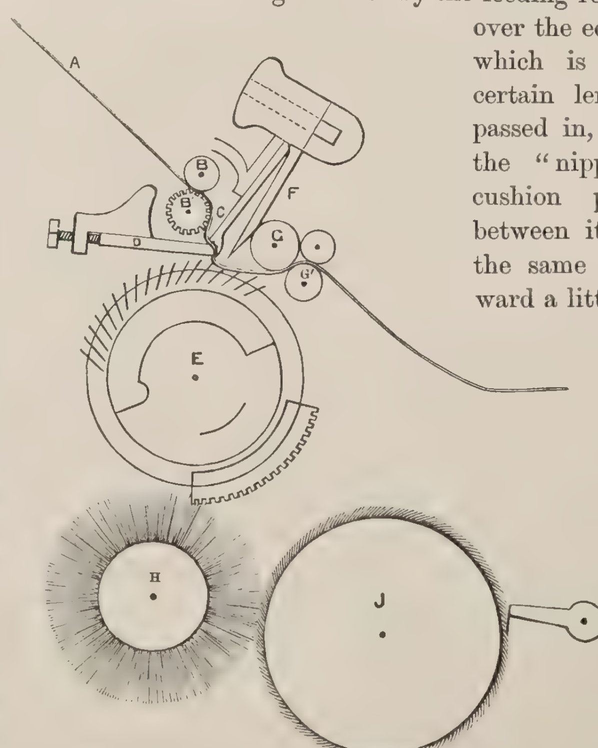


Fig. 2.—Sectional View of Combing Machine.

comb of the series the teeth number a hundred to the inch. The combs, having passed through the wool, continue their journey round to operate on a fresh length of fibre; but on their way they have to pass over a revolving brush H, which removes their burden of short fibres, and transfers it to a doffer J, which is covered with cards. While this is going on, a fluted section of the combing cylinder has reached the cushion plate and nipper, and, these having relaxed their hold, receives the combed wool and carries it forward to the rollers laps the end of the fresh one, when a little pressure suffices to join the two, and the whole is drawn forward in a continuous web or sliver. This completes the operation. The short fibres which were transferred to the doffer are removed by a crank-and-comb in the form of a sliver, ready for spinning into coarser qualities of yarn. The machine, like most of the others used in the cotton manufacture, is a marvel of mechanism. It is, however, so complicated in its parts, that much skill and care are necessary to its successful working; and hence

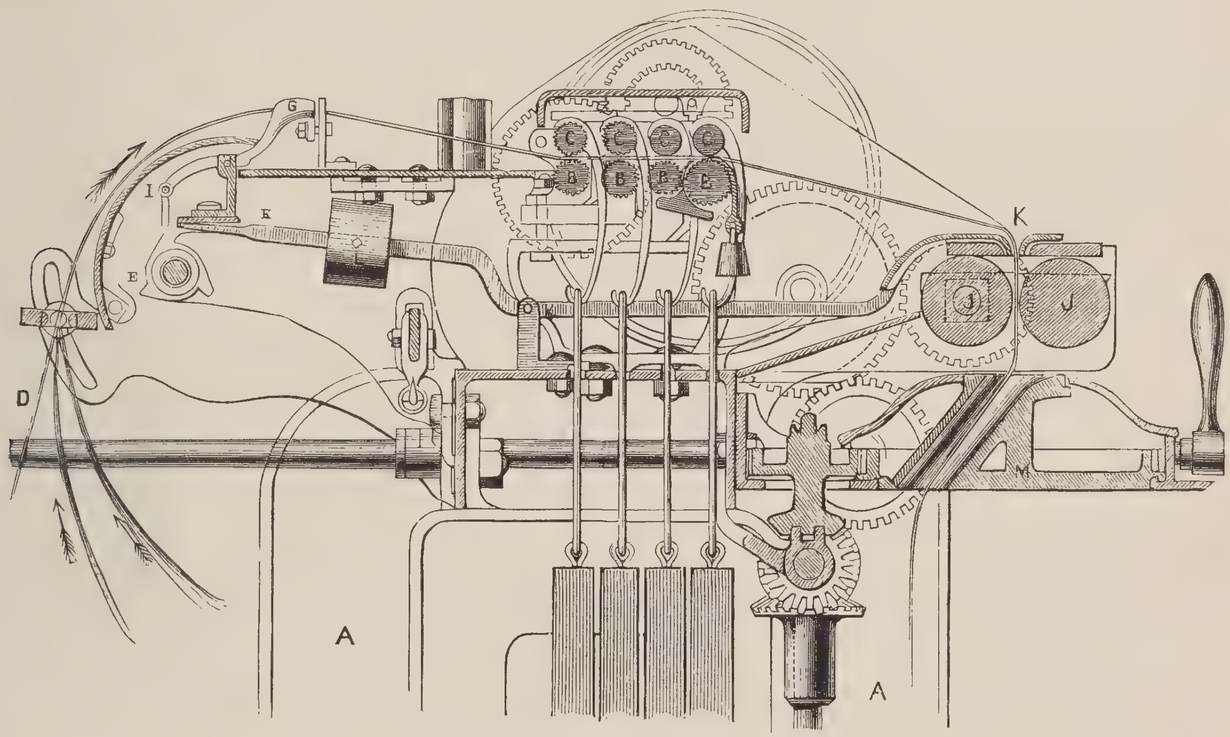


Fig. 3.—Sectional View of Drawing Frame.

(A A) framing of machine; (B B B B and C C C C) the drawing rollers; (D) slivers passing upward from the cans; (G) spoon lever which stops machine by dropping its end (I) into notched wheel (E); (K K) balanced lever, through one end of which the sliver passes which the other extends to wheel E and stops machine on breaking of sliver; (J J) rollers by which sliver is compressed; (M) the coiling disc, with sliver passing through its diagonal aperture.

G and G′. Just at the moment of release, a comb at the extremity of the rod F descends into the wool, and as the latter is carried forward to the delivery rollers, combs out the ends of the fibres which were held by the cushion plate and nipper. It will now be evident that the cotton, as it leaves this upper comb, is in the form of a row of fibres laid side by side somewhat like a loose fringe, corresponding in length to the width of the combs; and the next duty of the machine is to unite the successive combings into a sliver. This is done in a simple but highly ingenious manner. When the cotton has left the grasp of the nipper, and is partly sustained by the upper comb and the fluted part of the cylinder, the delivery rollers are reversed until the end of the previous combing emerges, and over-attempts have been made to discover simpler means for accomplishing the work. Several machines, for which it has been claimed that they can do more work with fewer parts, have been introduced to notice since Heilmann's invention came into use. Messrs. Dobson and Barlow, of Bolton, are among the makers of Heilmann's machine who have sought to simplify it; and they have produced a comber which has high claims to attention. In the illustrated catalogue of their exhibits at Paris in 1878, the firm set forth the advantages of their machine, and from that source we glean the following particulars. In Heilmann's machine, the setting of the nippers is a difficult and delicate operation, there being thirteen setting screws and eight joints in each nipper. The entire number of pieces in each

set of six Heilmann's nippers, with their fixings, is no less than 564, requiring about ten hours to adjust. In the new machine, with the same number of nippers, there are only 216 pieces, and the setting does not occupy more than half an hour. The cushion plate is dispensed with, and the nipper holds the cotton against the fluted feed roller. The cotton is drawn up into the top comb by the detaching rollers, which draw it in a straight line from the grip of the two feed rollers, thus combining great simplicity with efficiency. In almost every other detail of the machine improvements have been effected, but these it is not necessary to describe here. In the year 1869, Mr. Joseph Imbs, a native of France, patented a combing machine of which great things were expected. The English patent was secured by Messrs. Curtis, Parr, and Madeley, of Manchester, who introduced the machine to the trade a few years ago. This comber differs widely from that of Heilmann. The lap of cotton enters the machine over a small movable table covered with leather; and when a sufficient end for the combs to operate upon has passed over the edge of the table, a nipper descends and holds it fast. There are only two combs, and these are placed close together, and so arranged that at the moment of the nipper descending they rise and pierce the cotton from beneath. The table and nipper then move backward a little way, and in doing so break the lap and comb the ends of the fibres, which project beyond, but are yet retained in their grasp. The tail end of the tuft which has been detached is combed at the same time, as before the rupture took place the forward end of the fibres had been caught by a nipping roller, and in being drawn in by that the fibres have to pass through the combs. As soon as the operation is completed, the combs descend, and are cleared of any short fibres and motes they may have caught. The combed cotton is drawn forward until it reaches a circular brush, by which it is transferred to a card cylinder. From the latter it is stripped in the ordinary way by a doffing comb, and emerges from the machine in the form of a sliver. The short fibres are also collected on a card roller, and are delivered in the same way. Of this machine, Mr. Evan Leigh says: —"The difference in the combing action betwixt Heilmann's machine and Imbs' is very conspicuous, the former passing, by a rotary motion, a series of combs varying in fineness from fifty to seventy teeth to the inch, through *one* end of the fibres; whilst Imbs' machine pierces the fibres close to the nip in both sides before the web is drawn asunder, when one side is combed by the drawing back of the slivers, and the other by the advance of the same through the action of the forward nip. The quantity of waste made depends in a great measure upon the fineness of the combs. It is said to be capable of using laps of 14 dwts. to the yard, whilst Heilmann's can only use laps of 9 dwts., and with such laps can turn out 320lb. per week, making about 11 per cent. of waste, which appears to contain no long staple. If this statement proves correct, the days of the finisher card are numbered, for no carding engine can produce as good a quality of work as a well-constructed combing machine."

Great as is the change worked on the cotton fibres by the carding engine and the combing machine, they have on leaving them to undergo further treatment before they are ready to be twisted into yarn. The cards extract knotted filaments and various impurities, but they leave many of the fibres doubled and crossed over their fellows, and in that condition the cotton cannot be spun into yarn of the finer qualities. It is necessary, therefore, to open out the doubled fibres, and arrange all in a perfectly parallel way; and that is accomplished by "drawing." If a small quantity of the carded cotton be taken up, it will be seen to be in the condition described; and if it be drawn apart several times between the finger and thumb of each hand, all doubling and crossing will disappear, and the fibres will be arranged parallel to each other. What is done by the fingers in this simple experiment is exactly what is achieved on a larger scale by the drawing frame, the machine next in order to the carding engine—except in the case of the longer-stapled cotton intended for the finest quality of yarn, which, as already stated, is combed instead of being put through the second carder. The drawing frame (Fig. 3) is an exceedingly simple piece of mechanism, consisting merely of several pairs of rollers driven at different velocities, so as to elongate the sliver passing through them. Usually four pairs of rollers are used, arranged thus (Fig. 4):—The rollers, which are made of wood, are about $1\frac{1}{4}$ inches in diameter. The lower ones are fluted, whilst the top ones are, with the exception of the first, which is also fluted, clothed with flannel and leather, nicely joined at the edges, so as to form a perfectly smooth surface, and at the same time be somewhat elastic. The

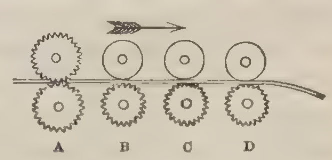


Fig. 4.—Arrangement of Rollers in the Drawing Frame.

top rollers are pressed down upon the lower ones by means of weights attached to their axles. Only the lower rollers are actuated by the motive power, the upper ones revolving by the friction of the sliver. Usually the drawing frame is constructed for three "deliveries"—or, in other words, with three sets of rollers. Formerly the rollers were rigid and continuous from one side of the machine to the other, with the surface divided into sections corresponding to the number of deliveries; but this arrangement sometimes produced bad work, through irregularities in the thickness of the sliver. To remedy this, Mr. Evan Leigh produced his loose boss roller, which is now in general use. This roller may be described as a tube placed on an axle, but having room to move freely round it, and also to accommodate its plane to the surface of the cotton passing under it. It is found sufficient in practice to introduce the loose boss roller as the upper of the front pair. To bring the machine into operation, the worker places behind each head a number of cans filled with slivers from the carding engine, and feeds into each set of rollers as many ends of slivers as may be considered desirable for the quality of cotton being dealt with. Sometimes as many as eight slivers are combined and drawn into one; in other cases, not more than three or four are taken at once. Between the cans and the rollers are a series of "spoons," or curved levers, and over these the slivers have to pass—one sliver to each. These levers perform an important duty. The slivers are so tender as to be very easily broken, and should the drawing be allowed to proceed after a breakage has taken place, a serious irregularity would be caused in the work. Before the spoon lever was invented, it was necessary for the machine attendant to keep a careful watch for breakages, and to stop the machine immediately on one occurring. The spoon lever is a silent monitor, which releases the attendant from the necessity for watching. The instant a break occurs, and the pressure of the sliver on the lever is consequently removed, the balance is disturbed, and the end of the lever drops into contact with a notched wheel, and brings the machine to a stand. Between the spoon levers and the rollers are curved plates, which guide the slivers into contact with each other, so that they reach the rollers in the form of a broad ribbon or lap. On leaving the rollers, the cotton has the form of a greatly-attenuated web, which the slightest puff of air would seem sufficient to break. It passes on to a table, and disappears downward through a funnel-shaped aperture, which squeezes it into the form of a cylindrical cord. Beneath the aperture are a pair of smooth rollers, which press the sliver, and give it a degree of cohesion sufficient to fit it for subsequent operations. The funnel-shaped opening is formed in the end of a nicely-adjusted lever, which, in the event of a break occurring, stops the machine in the same way as the spoon lever. Following the course of the sliver, we next find it enter an opening in the crown of a disc, and pass thence to a can beneath. This disc is an ingenious contrivance. Arkwright made his cans revolve, and so coil the sliver evenly as they received it. This disc is an improvement on that method. The aperture through which the sliver passes takes a diagonal course from the crown to the base of the disc, and as the latter revolves the sliver is deposited in neat and even coils. The "coiling motion," as it is called, was patented about forty years ago by Messrs. Tatham and Cheetham, of Rochdale, and is now almost universally attached to drawing frames and carding engines. For the finer qualities of yarn, it is customary to send the cotton through the drawing frame as many as six times. At the first of these drawings, eight carding-engine slivers are drawn into one; next, of the slivers so formed four are drawn into one; the subsequent drawings being seven into one, six into one, six into one, and six into one. By multiplying these numerators, we get 48,384, to which may be added another doubling on the bobbin-and-fly frame, making nearly 100,000 times that the relative positions of the fibres have been changed in the course of their being brought into parallel order. Referring to the number of drawings considered necessary, Mr. Leigh says:—"There is much difference of opinion among practical men as to the number of doublings which ought to be given in the drawing process. It is, however, certain that the more it is doubled and drawn out, the straighter the cotton fibres lie; but by carrying this process too far other evils are produced—viz., expense is incurred, and the material is somewhat weakened. American cotton, as a rule, requires less doubling and drawing in this operation than most other varieties, whether long or short; and where Orleans, &c., is exclusively used, it is recommended that it should be put through two heads only, having eight ends each into one, giving 64 doublings for yarns up to No. 34. In other cottons of more stubborn character, three heads of drawings are necessary, giving altogether 512 doublings for the same numbers. Some spinners put up three ends to each boss, working six into one, which three times over gives 216.

Where frames have only three rows of rollers, less drawing power and shorter bosses, this is better, for this reason—that when too thick it is apt to spring the top rollers, and never becomes so well drawn, as the fibres are held tight in the centre of the sliver, and loose at the edges; it ought, therefore, to be spread out on the bosses as much as possible to make sound yarn, care being especially taken that one end never rides upon another."

MODEL ESTABLISHMENTS.—V.

THE SAINT ROLLOX CHEMICAL WORKS, GLASGOW.

By James G. Bertram, Author of "The Harvest of the Sea."

Among the prominent industrial establishments of the West of Scotland, the great works of Messrs. Charles Tennant and Co., of Saint Rollox, in the city of Glasgow, must be assigned a chief place, being the largest of their kind in the country, not only as regards the extent of their premises and the number of hands employed, but also for the variety of their productions. The total area of ground now occupied is about 130 acres, of which nearly 90 are covered by erections of various kinds devoted to boilers, furnaces, retorts, towers, and chambers of various descriptions, *facile princeps* among which is the great chimney designed by the late Professor Macquorn Rankine, measuring 455½ feet from foundation to top. This stalk, as well from its towering height as from the elevated position on which it stands, can be seen at a great distance from Glasgow; whilst its utility as a sanitary agent, in carrying off the noxious fumes thrown off from an extensive and active chemical manufactory, is universally acknowledged. The works of Messrs. Tennant and Co. were commenced in the latter end of the last century, the firm being then Tennant and Knox. By slow degrees they have attained to their present magnitude, the space originally occupied being about three acres.

The products and by-products of Saint Rollox, are sulphuric and hydrochloric acids; soda ash, soda crystals, and caustic soda; recovered carbonate and peroxide of manganese; bleaching powder; recovered sulphur, as also soap: each product and by-product being, in a sense, the complement of the other. In addition to these important articles of commerce, everything required for carrying on a gigantic business is made within the place. The barrels in which the manufactured products are sent out are constructed by machinery; constant employment being given at Saint Rollox to upwards of 1,200 persons, many of whom are skilled workmen—blacksmiths, engineers, plumbers, tinsmiths, and cart and wagon makers. Gas and bricks are made within the premises; there is a casting department, and likewise a branch for the sawing and shaping of timber. The raw materials which are used in the manufactures at Saint Rollox are salt, lime (over 80,000 tons of which are required every year), and pyrites. Of coal, over 120,000 tons per annum are consumed in the works.

Out of this bald list of raw materials the fortunes of Saint Rollox have been consolidated. Mr. Charles Tennant, the founder of the works, when engaged in bleaching operations at Darnley, was so fortunate as to discover a mode of completely revolutionising the processes then in use for the bleaching of cloths and yarns. Previous to the year 1798, bleaching was chiefly accomplished by means of a solution of chlorine, the bleaching action of which was first discovered by Berthollet in 1785, and shown to the celebrated James Watt in the following year, during which it was practically tested by him in the neighbourhood of Glasgow; whilst a year afterwards the then Duke of Gordon, in conjunction with Professor Copeland, established works at Aberdeen for the supply of this material. It was speedily discovered, however, that this liquor both damaged the fabrics to which it was applied and injured the workmen, so that its power required, in consequence, to be modified by the introduction of a portion of potash—an improvement which met with the approval of all who were employed in that method of bleaching. At this particular period, Mr. Charles Tennant had worked out and patented a process in which lime instead of potash was used; and, in conjunction with Mr. C. M'Intosh and others, he began a successful manufacture of "lime-bleaching liquor," which for a time came into very general use throughout Scotland. However, a dispute regarding the rights under the patent caused the manufacture of this

The St. Rollox Chemical Works, Glasgow.

substance to be abandoned; and, in the course of the following year, Mr. Tennant, determined to provide for a want of the time, had discovered and patented the article which gave celebrity to his name, and assured the fortunes of himself and his successors. This was a dry compound of lime and chlorine, which was long known as Tennant's bleaching salt, and which, as bleaching powder, has been in use ever since. It is at present the staple article of manufacture at Saint Rollox, and it was for the manufacture of it that the works there were begun. The compound was prepared originally in a somewhat primitive fashion in a leaden still, heated by a water-bath, and containing a mixture of salt, manganese, and sulphuric acid. The projector of Saint Rollox could not at that time, we believe, have had any idea of the magnitude to which the establishment would attain, or of the economy of time and material, or the perfection of apparatus, which would one day confer distinction on the firm. It is to the Tennants and other industrial pioneers that Glasgow owes its present commercial grandeur. At the end of the eighteenth century it was a very small place indeed, and the Clyde of that day was but an insignificant fishing stream. That river has since become, however, the cradle of steam navigation, and is now one of the greatest highways of British commerce, the tonnage of the ships which use it being over two and a quarter millions per annum. It is also to the liberality of such men as the Tennants that the second city of the Empire owes the magnificent new pile of buildings where its great University has found lodgment—the University in which Adam Smith, the author of "The Wealth of Nations," was both pupil and professor! The works of Saint Rollox, with their labyrinthine pipes and aqueducts, their old towers and new chambers, are typical of the great hive of human industry which is spread around; on all sides the old is making room for the new—old buildings and insanitary streets are being removed, and buildings of a newer style are taking their places. The rude Glasgow of Rob Roy and Bailie Nicol Jarvie has vanished, and a fine modern city has taken its place.

As a general rule, the following were the proportions of the materials used in the preparation of the bleaching powder, as originally patented (1800):—Vitriol 4, manganese 2, water 4, salt 4¼. Occasional experiments were, from time to time, tried with muriates of potash and lime and magnesia, with the view of enhancing the value of the by-products. As soon as the manufacture of the bleaching powder was fairly set going, a new branch of industry was established at Saint Rollox—namely the making of sulphuric acid. Vitriol in large quantities being a chief necessary of the manufacture for liberating the chlorine, it was necessary to purchase it; but the price being £60 per ton, it was at once seen that it would not only be cheaper, but also more convenient, to make it on the premises. The quantity of vitriol required at Saint Rollox in these early days of its history amounted, in the course of the year, to 252,270lb., and the value of the bleaching salt sold in the same period (151,117lb.) was £7,500. In 1803, six chambers were completed, and at once utilised, at a cost of £50 each; whilst in the course of the next four years, eight more chambers were added to the works. Two years later there were in operation at Saint Rollox twenty-six chambers in all, which number had been increased at the end of 1811 by other six, which were constructed according to the latest fashion, with furnaces for burning the sulphur externally, and leading in the gases by flues—a method which of itself denoted a great improvement in the manufacture, as at first the nitre and sulphur were burned out in a vessel contained in the interior of the chamber. The systems on which the furnaces at Saint Rollox were originally worked was that of Messrs. Bealy, as in operation at Radcliffe, near Manchester; the materials used in producing the acid being sulphur and nitre, in the proportion of seven of the former to one of the latter. The original leaden chambers erected at these works were from 6 to 8 feet square; the present chambers are vastly superior, and of far greater magnitude, ranging from 80 to 200 feet in length, and are 20 feet in width and 21 in height. In addition to these chambers, there are at Saint Rollox, for the rectifying of that portion of the acid which is sold, two very valuable platinum stills, 3 feet in diameter, which turn out 13 tons per diem. The present machinery and apparatus are of the most approved description, and, in the adaptation of means to a given end, are as perfect as possible. During the two and a half hours which it takes to walk through the works, the eye is puzzled with the many curious contrivances which are in use at Saint Rollox, in the shape of circular roasting machines of giant proportions, mighty furnaces in a perpetual roar, lofty water towers, great boilers, vast lengths of piping, water conduits, and various other erections requisite to the products which are issued from the works.

The production of caustic soda commenced at Saint Rollox in 1844, but there being no great

demand for the article, the making of it after a time was given up, but in 1875 it was again successfully resumed. The process of manganese recovery employed at Saint Rollox is one invented by Mr. T. C. Dunlop in 1855: it is described in most modern works of technical chemistry. The process gives a black oxide of manganese of high strength.

The utilisation of waste substances, and the best modes of economising the by-products, has since the commencement of the manufacture greatly occupied the attention of members of the firm. Messrs. Tennant have no reason to complain of a want of success as regards this important feature of their manufactory. They were successful at an early period with a plan of theirs for re-burning the sulphur ashes, which plan they at once turned to account by purchasing the residues of other makers at a cost of about £5 per ton, and from the *débris* so acquired they were able to extract from 25 to 50 per cent. of sulphur. The plan, as finally adjusted, was ingenious, and lay in the attachment of two chambers to one central furnace, which burned the sulphur ashes mixed with portions of fresh sulphur and nitre. By this mode of working with a double chamber, continuous operations were carried on, the gas passing for a time into one chamber and then into the other, so that each was allowed to cool and condense alternately. The strength of the chamber acid made at Saint Rollox by means of this plan of working gradually increased as the method was perfected, and rose after the introduction of steam (in 1813–4) from 50° to 120° Twaddel. Pyrites came into use at Saint Rollox in the year 1840. After being roasted at Saint Rollox, the pyrites are further manipulated by a copper-extracting company.

The group of processes which comprises the alkali manufacture, as now carried on at Saint Rollox, and which constitutes the most important chemical industry of the day, may be outlined as follows, on the authority of a paper contributed by Mr. Mactear, of the firm of Messrs. Tennant and Co., to the Philosophical Society of Glasgow. There is the production of sulphuric acid from pyrites; the decomposition of common salt by the sulphuric acid, with the production of sulphate of soda and hydrochloric acid; the utilisation of the hydrochloric acid, either for the manufacture of bleaching powder, chlorate of potash, bicarbonate of soda or sulphur, which is recovered from the waste produced in the final process of the alkali manufacture, as will be mentioned by and by; the conversion of the sulphate of soda, by its decomposition with carbon and carbonate of lime, into carbonate of soda and sulphide of calcium; and, lastly, the subsequent separation of these two compounds by lixiviation with water.

One of the features of the works at Saint Rollox, the new mechanical revolving furnace used in the alkali manufacture, and contrived by Mr. Mactear, deserves to be specially noticed as one of the most ingenious inventions of the day. It is desirable to note that it facilitates the work to a great degree; that it does the work much better, and at a greatly cheaper rate, the cost for labour being under 1s. per ton, which is less than one-third of finishing by hand. The saving in coal is also considerable —not less than 25 per cent. It is another advantage of these mechanical furnaces that they dispense with so much hand labour; three good men can quite well attend on two furnaces, getting the aid of two labourers during the drawing of the charges, which takes place some five or six times during every twenty-four hours. These rotatory furnaces are rapidly superseding all the hand furnaces in the various alkali works of the country. As Mr. Mactear said at Plymouth, in a paper read before the British Association, "The great rise in wages, and the increasing scarcity of the class of labourers needed for the various furnace operations, have stimulated the production of various ingenious inventions." That the "Mactear furnace" has proved a great success is evident from its coming into general use, and that it deserves the success it has attained is obvious from the fact of one of the new furnaces for the "finishing" of alkali being capable of turning out as much work as was formerly produced by fourteen or fifteen hand-worked furnaces.

The utilisation of the waste soda, which is incidental to the alkali manufacture, has been at all times a great source of anxiety; and it has always remained as a reproach against the Leblanc process that the two raw materials, sulphur and lime, are both, with trifling exception, completely lost as waste products; and, moreover, they form a refuse material which, by process of accumulation, becomes a clamant nuisance. At the Saint Rollox Works, the great problem of the regeneration of sulphur from soda waste has been solved by the fertile brain of Mr. Mactear. The process invented by that gentleman owes its origin to the great nuisance produced by the natural oxidation of the enormous heaps of alkali waste which had been accumulating at Saint Rollox for a period of forty years. Saturated with water from natural springs, and also with the rainfall, there was a flow of "yellow liquor" from the waste, which was not unnaturally objected to by the

inhabitants of "St. Mungo's favourite city" because of its ultimately finding its way into the river Clyde. Many devices were resorted to on behalf of the firm to abate this nuisance, but without effect; the immediate neighbourhood was, to some extent, relieved of the pest by the laying down of a pipe, which carried the liquor direct to the river, instead of being longer allowed to fall into the great Pinkston Burn sewer, but what was done did not tend to sweeten the waters of the Clyde, nor did it put money into the pockets of the Saint Rollox proprietors. By the process thought out—after, however, encountering many failures—by Mr. Mactear, a ton of sulphur can be recovered from the soda waste at a cost of 61s., which admits of a handsome profit, although the price of the plant necessary for the operation is a little over £2,000. The apparatus is capable of making 35 tons of sulphur weekly; and at Saint Rollox, we believe, the quantity of sulphur recovered may be estimated at about 100 tons a month. Professor Ferguson, of Glasgow, has given a brief *précis* of the Mactear process, which, he says, "consists in the partial oxidation of the soda waste, which is then dissolved in water, and decomposed hot with hydrochloric acid. Sulphur precipitates in a finely-divided state. It is allowed to settle, and then it is dried and fused." The sulphur obtained is of excellent quality, and is in great demand for the making of gunpowder. The residual liquors, after the process has been exhausted, are without any odour and quite harmless; indeed, they are rather beneficial than otherwise in the flushing of sewers. The great merit of the Mactear process, in comparison with any other, is that it is thoroughly practical, that it makes the best possible use of the waste material, that it "pays," and that it prevents a public nuisance which must ultimately have exercised a deleterious influence on the health of the city of Glasgow.

One of the benefits of a manufactory conducted on such a scale is the reduction of the price at which useful goods can be sold—persons who buy a penny packet of bleaching powder are scarcely able to realise the fact that it is being made in tons, and that expensive machinery has been patiently devised from time to time in order to save labour and quicken production. It may be interesting to mention that the salt required in the manufactures carried on at Saint Rollox, cost at one time as much as £18 13s. 4d. per ton. Now it only costs about the odd shillings! Some interesting details of the salt manufacture of Scotland could be given were this the proper place for them. When the Saint Rollox Works were started, there was a duty exacted on the salt made in Scotland of £12 per ton, and at that period the produce of 118 pans was 8,750 tons per annum. Salt, it is needless to say, plays an important part in an alkali manufacture. The great works of Saint Rollox are no longer "secret." The processes carried on cannot be concealed from the hundreds of persons who are employed by the firm, nor is it necessary they should; but even at present, letters sometimes come to the workmen addressed "Saint Rollox Sacred Works." There are various other chemical manufactories in the West of Scotland, but those at Saint Rollox are the greatest in magnitude, and it is due to Messrs. Tennant and Co. to acknowledge that for the eighty years which have elapsed since the place was founded, they have greatly helped to contribute to the wonderful prosperity of Glasgow.

SHIP BUILDING.—X.

WATER-TIGHT SUB-DIVISION IN IRON SHIPS.

IT is by no means an easy matter to determine whether a ship is seaworthy or not. Her structural arrangements, age, condition, lading, and equipment all have to be considered, as well as the service upon which she is to be employed. Legal enactments to cover these diverse features in the problem have been again and again attempted, but not with much success. Security for life and property at sea never have been, and from the very nature of the case, never can be obtained from the most carefully drawn and efficiently administered Act of Parliament. Ocean navigation must be attended with risks; and although these risks may be lessened by care and foresight on the part of the ship builder, the ship-owner, and the ship captain, yet absolute security is unattainable. This is a truism, no doubt; but one that is apt to be overlooked in these days of steam navigation. We are accustomed to hear of the regular departures, and almost as regular arrivals of our ocean steamers.

despite the changes that so frequently occur in wind and weather. The trans-Atlantic voyage is regarded rather as a pleasure trip than as a voyage involving possible danger or disaster; and Anglo-Indians think little or nothing of the risks attending "a run home." Now and again, it is true, some sad exception happens; a noble vessel carrying hundreds of passengers is lost, and then for awhile our wonted confidence is shaken; but no long time elapses before such accidents are almost forgotten, and confidence is restored in the seaworthiness of our ships. Of course, it will be understood that we are here speaking of ships possessing good characters and owned by honest men; not of the ships which Mr. Plimsoll made infamous, which were owned and worked by unscrupulous men, whose only desire was to enrich themselves, even at the cost of the lives of their sailors. Nor can it be doubted by any one who will investigate the Parliamentary Papers published by the Royal Commission on Unseaworthy Ships, that by far the greater number of British ships belong to the former, not to the latter class. Mr. Plimsoll himself was careful to separate the honourable from the dishonourable ship-owners, and all his efforts were aimed at enforcing upon those who needed compulsion, a practice resembling that which honourable ship-owners followed of their own free will. The agitation in which Mr. Plimsoll took the chief part, did not succeed in establishing the stringent regulations which it was proposed to enforce; nor is this result to be regretted. Undue interference on the part of the Board of Trade with our mercantile marine could scarcely fail to be accompanied with injury to our shipping and commerce; for while we hold the first place as a maritime power, we are not without rivals, who would be prompt to seize upon any advantage resulting from legal enactments which pressed heavily upon British ships alone. The main results of the Plimsoll agitation may be summed up in the statement that the Board of Trade has been endowed with large discretionary powers, in carrying on the survey of merchant ships. The staff of surveying officers has been considerably increased in number, and a more real oversight is exercised upon the condition and lading of ships. In not a few cases vessels have been detained by officers of the Board of Trade, because they were considered to be overladen, or unseaworthy from some other cause; but it is only at the stage when a ship is ready to go to sea, that the surveyor has, as a rule, the power of interference. Ship-owners or their agents and representatives work freely in preparing the ship for sea, but all the time they are aware that an independent authority will in the end have to decide whether or not the ship is fit to leave port. When disagreements arise and the decision of the surveyor is considered unfair, there is a power of appeal to a special court. This arrangement is obviously a compromise, and depends for its successful working largely upon the wisdom and discretion of the surveyors. On the whole the plan appears to have given satisfaction, although complaints have not been wanting of undue interference by officials. It is worth notice, however, that no serious attempt has been made to repeal the last Merchant Shipping Act; and this is good evidence that its terrors are mainly for those evil-doers who could only be reached with difficulty before the Act was passed.

Every one agrees that the risks to be run in ocean navigation should be minimised as far as possible; but there are very serious differences of opinion as to the range of that possibility in some directions. Take, for example, precautions against *foundering*—one of the most common causes of loss. A ship founders when she is either filled with water by being "swamped," the seas breaking over her and passing down the hatchways; or when she has her sides or bottom broken through by collision or other accident, and the water can find access to her interior. Numerous cases are on record illustrating both these kinds of foundering; but with thin-skinned iron ships damage to the skin is mostly to be feared. A blow of moderate force may suffice to break a hole through the iron plating large enough to admit such quantities of water as will overpower the pumps and endanger the vessel, if she be constructed on the ordinary plan, and not sub-divided into numerous water-tight compartments. In fact, iron ships are far more liable than wooden ships to loss by foundering, if they are not furnished with water-tight sub-divisions; and in the great majority of iron ships such sub-divisions are not sufficiently numerous to keep the ships afloat, when they are but moderately damaged. More minute water-tight sub-division is a crying want in ordinary iron merchant ships, used both for cargo and passenger trades; yet, strange to say, there are no regulations in existence to bind a ship-owner to provide this simple and efficient means of safety. It is urged that when a cargo-carrying iron ship has her hold space cut up into small compartments by water-tight partitions, her usefulness and capacity for stowage of a miscellaneous cargo are greatly reduced. This argument doubtless has considerable

weight, although for many trades well-divided ships are no less suitable and efficient than ships not sub-divided, and can successfully compete with the latter class. But even if it be admitted that in cargo-carrying vessels water-tight sub-division should not be insisted upon, the risks of foundering being accepted as a set-off against greater facilities for stowage, it can scarcely be argued that in passenger or emigrant ships no special precautions should be taken. When large numbers of people are carried, it is surely not too much to demand that considerations of safety should reign paramount, and those for convenience in stowage of hold be subordinated. This is true in many cases, but unfortunately not in all, or perhaps in the majority of passenger ships with iron hulls. Ship-owners have of late years been giving more attention to the matter, but even now it is a fact that by far the larger number of iron ships run serious risks of being sunk if a hole of small size is broken through their skins, anywhere except very close to the extremities. We state this fact not as an alarmist might, but simply to enforce the need of a change in this feature of iron ship construction; and further it must be admitted that the change is far more likely to be brought about by the pressure of public opinion than by any action of the Board of Trade. If passengers appreciated more truly the advantages of water-tight sub-division, and patronised vessels wherein such sub-division had been efficiently carried out, the system would speedily prevail, notwithstanding the objections that are raised against it. On the other hand, the owners of ships possessing this good quality would do wisely in bringing it more prominently before the public than they now do. Excellent state rooms, magnificent saloons, a liberal diet, good accommodation, high speed, and good behaviour, are all features which are well advertised; but one hears much less respecting the extent to which water-tight sub-division is carried in first-class passenger steamers, or of the provision for safety against foundering.

If legal protection be given to any class of passengers, it should obviously be afforded to emigrants, consisting, as they do, almost exclusively of poor and comparatively ignorant people, who have no choice but to embark in vessels selected by responsible officials. This principle is received and acted upon to a very large extent already. The Board of Trade regulations cover the arrangements for berthing, light, ventilation, boats, life-buoys, provisions, water, medicine, medical attendance, and very many other details considered important as regards the health and comfort of emigrants; but nothing is said as to water-tight sub-division in iron ships. Readers will have noticed from time to time paragraphs in the newspapers, stating that the splendid ship —— has sailed for one of our Australasian colonies with 300 or 400 souls on board. Few readers of such paragraphs are aware, however, that in nearly all cases these sailing iron emigrant ships are practically destitute of water-tight sub-division. The common practice is to fit these vessels with one water-tight bulk-head only near the bow, the intention being to provide against damage to the bow in case of collision—hence, this bulk-head is generally known as the "collision bulk-head." In numberless instances the collision bulk-head has saved the vessel which struck another "bow on;" but the common case is for the iron ship which is struck to founder, if her broadside is penetrated below water. Speaking generally, it may be said that an ordinary iron sailing-ship used for emigrant service can scarcely have a chance of keeping afloat if she is seriously damaged by collision abaft her single bulk-head; and although the chances of collision may be few, while the voyages made in safety by such vessels are very many, yet we cannot refrain from expressing the opinion that no iron emigrant ship, propelled by sails or by steam, should be allowed to go to sea until the Board of Trade surveyors had satisfied themselves that she was efficiently sub-divided into water-tight compartments.

The Merchant Shipping Act of 1854 provided that every iron-hulled steam-ship should be divided into not less than *three* parts by transverse water-tight bulk-heads, in addition to a small water-tight compartment at the stern of screw steamers. A penalty not exceeding £100 was incurred by the owner who sent a ship to sea not divided in accordance with the Act. In 1862 these rules were repealed; and on the whole, the action must be commended; for the minimum number of bulk-heads required by the Act was altogether insufficient for safety in ships of large size, and the existence of such a law was liable to create a false impression as to what amount of sub-division was necessary or desirable. Ship-owners naturally preferred to be left free in the matter, and there was no endeavour on the part of those who should have led public opinion to substitute for the cancelled regulation one which gave a real guarantee of safety to passenger and emigrant ships.

Turning from Parliamentary regulations to the rules issued by Lloyd's Committee for building iron ships—which rules largely influence the practice of all British ship builders, and govern the classi-

fication upon which underwriters rely in insuring ships—one finds an absence of any requirement for efficient water-tight sub-division. An iron sailing-ship need only have a collision bulk-head : a steamer must have her engine room bounded by water-tight bulk-heads, and have, besides, two bulk-heads, one near the bow for safety against collision, a second near the stern. In very many cases these requirements are much more than met; but for purposes of classification the existence of a greater number of bulk-heads exercises no influence. The total number of bulk-heads fitted is usually recorded in the Register Book, and an underwriter probably has regard to this feature in a ship when deciding upon the terms for insurance of ship or cargo; but the general public knows nothing of these differences in construction in ships of nominally the same class.

Very many cases are on record where iron ships have been saved from foundering by water-tight sub-division; but we have no space for these narratives, interesting as they are. One sad example of an opposite kind must be mentioned, however. The troop ship *Birkenhead* foundered some years ago, when carrying a large number of troops, whose heroic behaviour in standing fast upon the deck as the ship sank will never be forgotten. One chapter of that sad but glorious story is too often omitted; it is brief, but full of warning. As first built, the *Birkenhead* was well divided into water-tight compartments; but for the sake of convenience the partitions had been cut through to form passages, and when the hour of trial came this change proved fatal. Could any circumstance point more forcibly the remarks previously made on the necessity in passenger-carrying vessels of subordinating convenience to the provision of safety, so far as may be possible?

The popular prejudice against iron ships as compared with wood, was at the outset mainly based upon the supposed readiness of the former to sink on very small provocation. We have already exposed the fallacy of the opinion that "it is not *natural* for iron to swim" (*see* p. 148); but the popular prejudice in this case, as in many others, contains a fragment of truth. It is an undoubted fact that, when damaged, ordinary iron ships sink *more rapidly* than wood ships; and the explanation of this difference is very simple. The skin of the iron ship is more liable to serious fracture than the thick, tough planking of a wood ship; hence the area of the inlet-hole is likely to be greater in the iron ship, and the rate of inflow of water will be greater also. Nor is this all. The thin sides of the iron ship displace much less water than the thick sides of the wood ship, when the damage has been effected and water has entered the hold; in other words, the iron structure, when damaged, is less *buoyant* than the wood. Now, it is important to notice that the flotation or sinking of any ship when damaged, depends upon the volume of the space to which the water can find access through the damaged part. A timber-laden ship, for example, may be practically *unsinkable*, because her hold is filled with material having great bulk in proportion to its weight, and therefore leaving but a comparatively small volume to which water can find access. This same vessel with an empty hold might, if similarly damaged, sink rapidly, because the water could find access to a large space in the interior. One way of keeping ships afloat is, therefore, to pack them with some light wood or cork, leaving a small internal space; but this is clearly a very objectionable plan in most cases. Internal capacity for cargo-carrying or accommodation is a most important feature, and one that cannot be sacrificed. By means of sub-division into water-tight compartments, internal capacity can be left free, while the end served by light packing is attained—viz., *the space to which water can find access is limited.* This is the fundamental principle of all proper water-tight sub-division, and it is one of high antiquity. The Chinese from time immemorial have fitted transverse water-tight bulk-heads in their wooden junks. In special cases European nations have imitated their practice; as, for example, in wood vessels equipped for Arctic voyages. But it is in iron ships that the principle is of the highest value, for the reasons stated above. The best examples of its application are to be found in modern ships of war, which are exposed to special risks of under-water attacks by ramming or torpedoes. In the drawings attached (Fig. 1) a good example is given of the principal methods of sub-division in an iron-clad; only a few words of explanation will be needed. Throughout quite two-thirds of the length of the ship a "double bottom" extends (from A to K in profile); its usefulness was explained in the preceding chapter. The hold of the ship is sub-divided by three systems of water-tight iron partitions. First there are the vertical *transverse* bulk-heads; second, the *longitudinal* bulk-head at the centre of the ship, extending through engine and boiler rooms, and the other longitudinal bulk-heads forming boundaries to the coal spaces; third, there are the *horizontal* platforms and decks, which are especially valuable near the bow and stem. Besides these principal partitions, it will be remarked that those built

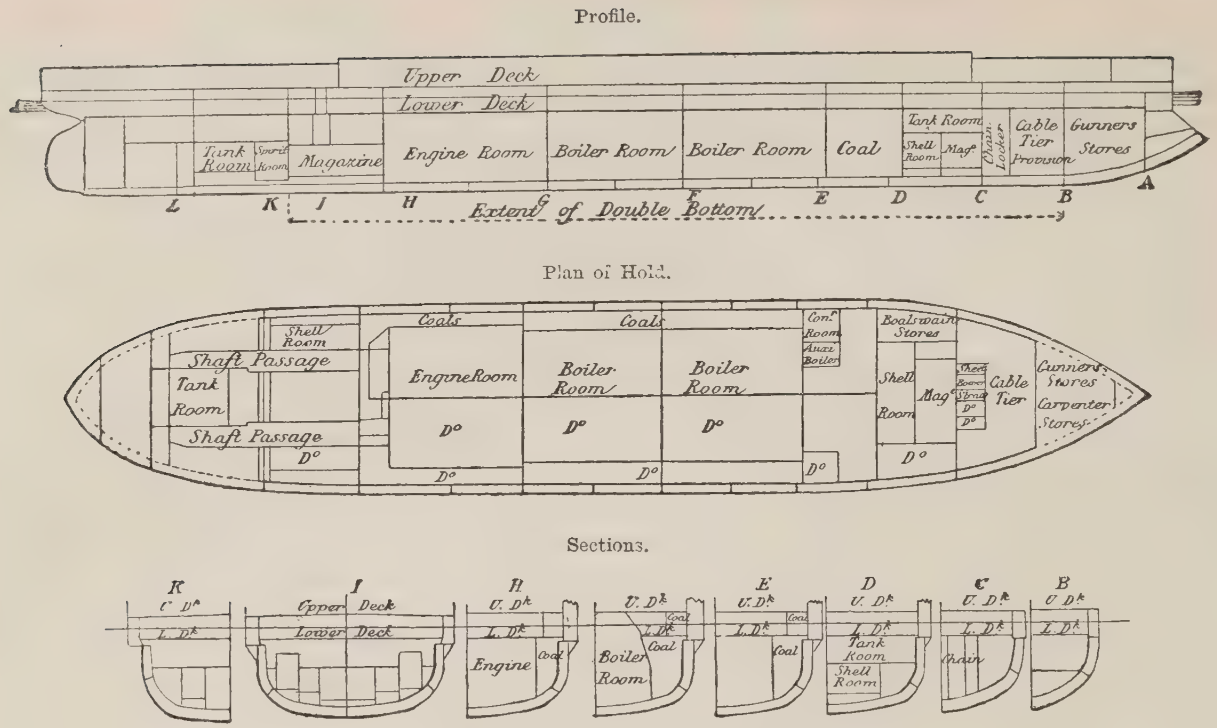


Fig. 1.—Water-tight Sub-division of an Iron-clad Ship.

primarily for purposes of stowage or convenience—inclosing magazines, shot rooms, shaft passages, &c. &c.—are also made water-tight. In some modern ironclads, the hold space is divided into no less than eighty to ninety compartments in this manner, and five or six of the largest of these can be filled with water without endangering the safety of the ship. It is not true that all ironclads are so well sub-divided; nor is it right to suppose that even the most minute sub-division possible can suffice to meet all modes of attack. The accidents which led to the loss of the *Vanguard* of the Royal Navy, and *Grosser Kurfürst* of the German navy, furnish illustrations of both these statements; for these ships were damaged in a most exceptional manner, and neither of them was sub-divided so well as many ironclads are. Both of them were, however, much superior in water-tight sub-division to iron merchant steamers, in which even good examples could scarcely keep afloat with two compartments thrown open to the sea, and others, above the average type, would be at the limit of safety with one compartment bilged.

In conclusion, we can only draw attention to the accompanying illustrations showing how water-tight doors are fitted in water-tight bulk-heads, when apertures have to be formed for passing from one compartment to another. All such apertures, of course, involve some risk, as it may happen that at the time of an accident the doors cannot be closed. This was the case in the *Vanguard;* had it been possible to close the doors between the engine and boiler rooms the ship would not have sunk. Hence, many persons have advocated the entire disuse of water-tight doors in bulk-heads, but general opinion is in favour of their retention, as a convenience, means being provided for closing the doors in the hold even when a compartment is flooded with water. Fig. 2 shows the detail of such an arrangement for a door sliding vertically. The shaft (*s*) is carried high up in the ship, and can be worked at the top; its rotation moves the door up or down, and when the door is closed (as in the drawing) its edges fit into wedge-shaped grooves in a frame bolted to the bulk-head, so making water-tight joints. In some cases doors are made to slide horizontally, instead of vertically; but the principle of working from above is carried out. The lower parts of hold spaces are, of course, most liable to be flooded, and "between decks" there is less danger of the doors being inaccessible. A simpler plan of hinged door is therefore fitted in many cases, especially in ships of war, to the upper parts of the bulk-heads. Fig. 3 shows this in detail, and the "Plan" enables one to see at a glance how the door is made water-tight. An angle-iron rim, surrounding the doorway, presses with its edges against a strip of indiarubber fastened to the door, and the door is secured by means of pivoted "clasps" or "handles" placed at close intervals around its edges. When hatchways or openings have to be cut in water-tight decks, or

platforms, hinged water-tight covers or scuttles are fitted to the openings, the principle of these fittings being very like that of the hinged door in Fig. 3.

The method of constructing transverse bulk-heads will be understood by reference to the drawing on page 205. In that case there is a special mode of attachment to the skin plating; but in ordinary iron ships with transverse ribs, the bulk-heads are simply attached to some of the ribs. Water-tightness in the joints of bulk-head plating is secured by arrangements similar to those illustrated on page 204; and after the work is finished, it is carefully tested by water-pressure, in all well-built ships.

When constructed with special regard to water-tight sub-division, iron ships are not only stronger, lighter, and more durable than wood ships; but they can also be made safer, especially against foundering and loss by fire. When the hull of a vessel is built of inflammable materials, like wood, a conflagration which once takes firm hold of a portion of the vessel is sure to spread. But with a well sub-divided iron hull there is a much greater chance of escape. The flames may be beaten back into the compartment in which they originate, or the compartment may be sealed up. The well-known case of the *Sarah Sands* illustrates these remarks; for she was kept afloat and brought home safely, although one end was completely burnt out, and although the bulk-head which saved the ship formed a partition between the magazine compartment and that on fire.

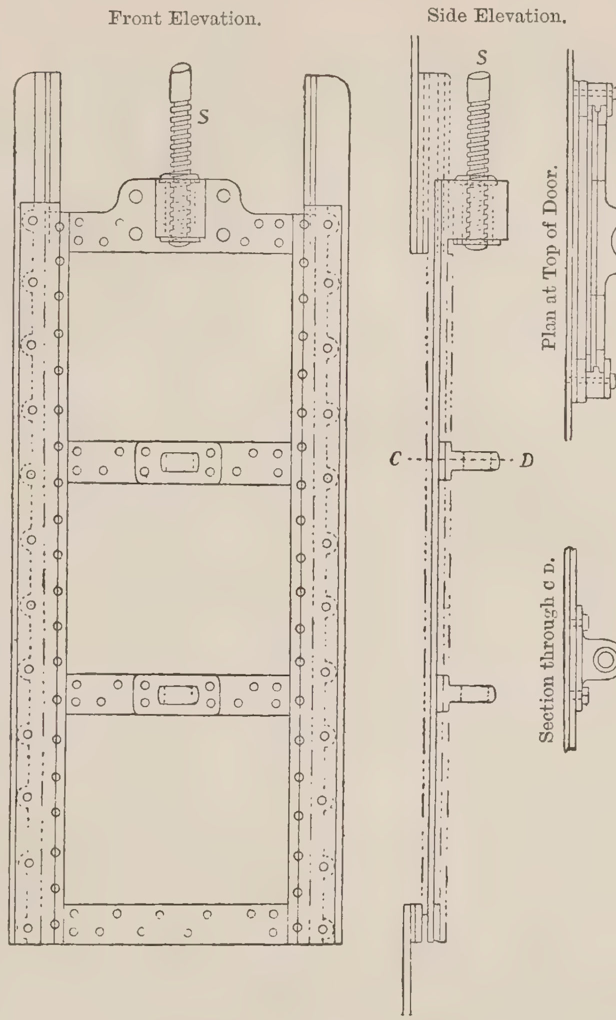
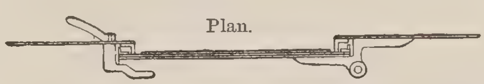


Fig. 2.—Vertical Sliding Door.



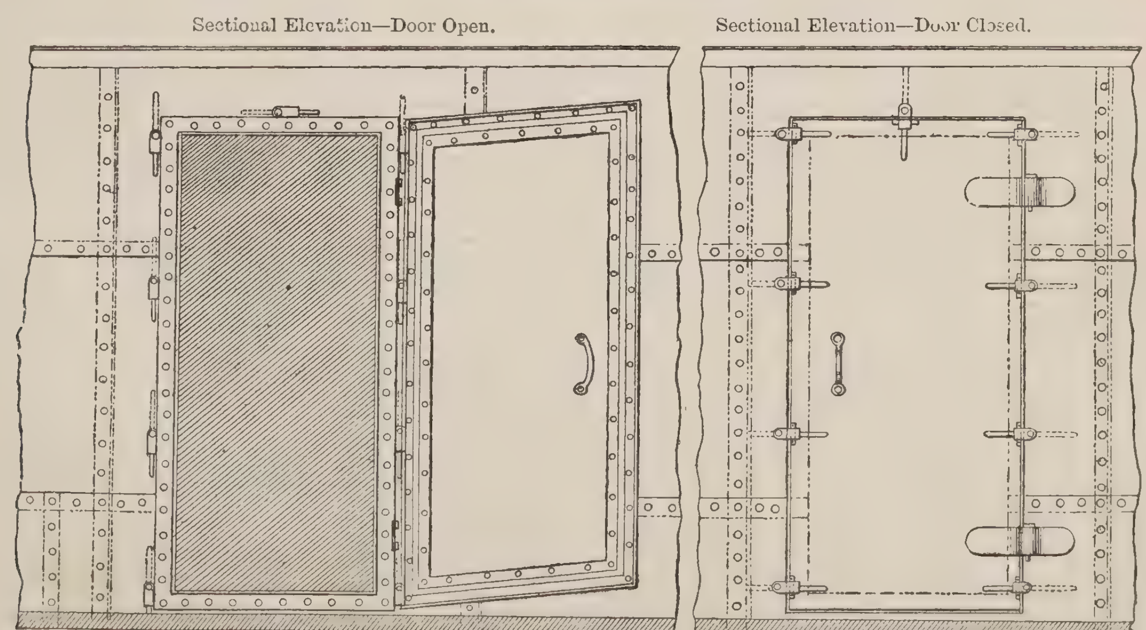


Fig. 3.—Water-tight Door Hinged.

HEMP, FLAX, AND JUTE.—IX.

FLAX-TOW CARDING—SPINNING—WEAVING—REMARKABLE ACHIEVEMENTS ON THE HAND LOOM.

By David Bremner, Author of "The Industries of Scotland."

THE short and rough fibres of flax extracted in the processes of scutching and hackling, and technically designated "tow," are far from being valueless, as from them are fashioned those coarser qualities of yarn and cloth which serve a thousand useful purposes. Through all the preparing processes of "line," or the longer and finer fibres of flax, the fibres are retained in a parallel position; but owing to the mode of its separation the tow is collected in tangled masses. It was necessary, therefore, in turning it to account, that special machines should be provided. As the condition of the material resembled that of wool and cotton in their raw state, the carding engine naturally suggested itself as a means for dealing with it, and on a modification of the cotton carder being tried it was found well adapted to the purpose. Two carding engines are used—one the "breaker" and the other the "finisher"—both of them of a larger and heavier make than the machine used in preparing cotton. The main cylinder is usually about 5 feet in diameter and 6 feet in length. The breaker is fitted with a feed apron or creeping table, on which the tow is spread in an even layer, the quantity placed on a given surface of the apron being determined by weight. The tow is taken from the apron by a pair of rollers 2½ inches in diameter, covered with stout carding. From these rollers it is caught by the carding on the main cylinder, or "swift" as it is called. The cylinder moves much faster than the rollers, so that the fibres are, as it were, snatched up by it and drawn into something like parallel order. The knotted parts become fixed on the points of the wires, and the clean fibres fall in among them. The knots are not allowed to travel far before they are caught by the first of a series of seven small rollers, called "workers." Each worker has an attendant roller, called a "stripper," against which its wires work, but which is not in contact with the main cylinder. Between the worker and the stripper the tangled fibres are combed out, and then returned to the swift. Should any knots escape the first pair of rollers, they will be caught by the second pair, and so on; and by the time the tow has made the circuit of the machine, its condition is very much improved. Experience having shown that the carding engine separates the tow into two or more distinct and recognisable qualities, means are now taken to keep these separate. This is done by the aid of three "doffers." The wires on the first of these barely touch the wires of the cylinder, and take off only the longer and finer fibres. The wires of the second are placed closer, and seize the fibres of medium size; while the third doffer is set so close as to clean out all the remaining fragments of tow. The separate qualities of fibre obtained in this way are applied to such different purposes as they are best suited to serve. The finisher carding engine is fed with a lap of the tow from the breaker. This lap is formed in a special machine, and consists of a number of "slivers" placed side by side. In the further preparation of tow for spinning, various machines are used. The screw-gill drawing machine was found unsuitable for dealing with the short fibres, as the fallers in descending not unfrequently dragged some of the tow with them, thus disarranging the drawing and clogging the apparatus. Messrs. Fairbairn and Co., of Leeds, devised a circular gill, which has completely removed the difficulty experienced in drawing tow. In their machine the hackles are fixed on the surface of small cylinders, each designed to deal with one sliver of carded tow, and the spikes are inclined backward from the direction of motion, so that as the cylinders revolve the spikes pass from the fibre without dragging any of it away. The same firm has also produced a tow-combing machine, which has met with considerable favour. It is an adaptation of Heilmann's famous invention. Having been carded or combed and drawn, the tow is roved and spun in the same way as line.

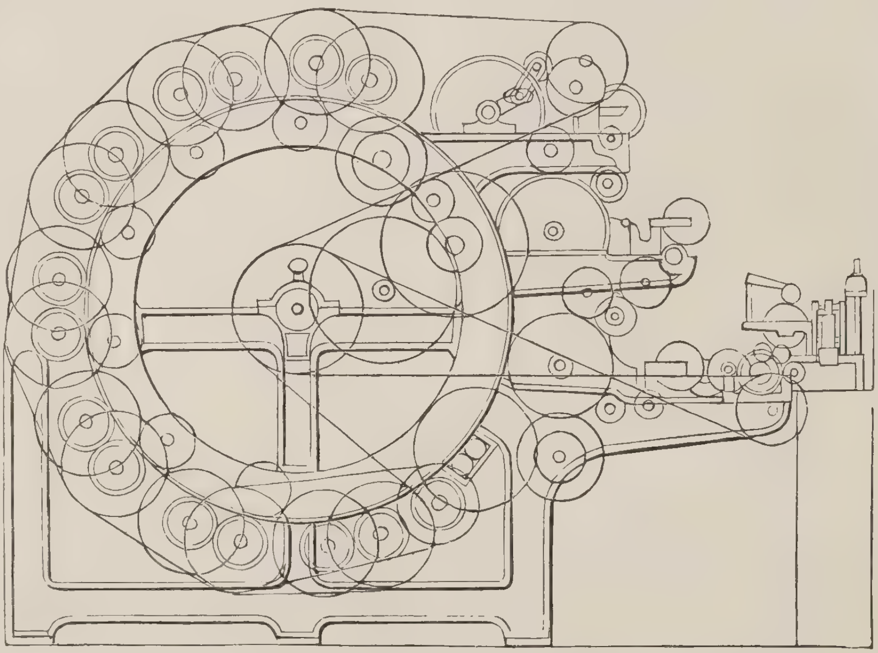
As the roving and spinning machines employed in flax mills are mainly modifications of those devised for working cotton, and will be found fully described in another part of this work, it is unnecessary to say much about them here. The roving frame for flax is the same as the drawing frame, so far as the back and front rollers and gills are concerned, but the sliver is more attenuated, and as it emerges from the last pair of rollers it is led to the throstles and twisted into a soft cord. Only one more process remains to complete the spinning, and that is accomplished on the spinning frame, which is furnished with from 200 to 300 spindles on the

throstle principle. There are three modes of spinning. "The first, and perhaps the oldest," says a high authority on the subject, "is that where the drawing and twisting are performed altogether with the material preserved dry, and without breaking or shortening the fibres. By the second method the spinner draws the fibres while dry, but wets them just at the moment before twisting. This method is the nearest imitation of hand spinning, and makes the yarn more solid and wiry than the first, as the fibres of flax, losing their elasticity when wet, unite and incorporate better with one another. The third mode of spinning has been much more recently introduced than either of the others, and by it the fibres are wetted to saturation previous to being drawn, whereby they are not only much reduced in length, but their degree of tension is increased by the partial solution of the gummy matter inherent in the flaxen material. Owing to this circumstance, equally good yarns can be produced by this mode of spinning from line or tow of inferior quality to what could be produced by either of the others; and not only that, but much finer yarns can now be spun than was possible previous to its introduction. It has, therefore, not only superseded all other methods of spinning for yarns, from 20's to the finest, but has much increased the extent and importance of the flax manufacture."

From the bobbins of the spinning frame the yarn is reeled into skeins or hanks. The "lea," a length of 300 yards, is the standard of yarn measure in England, Scotland, and Ireland, but the subsequent reckonings of quantity differ. Thus in England and Ireland ten leas make one hank, twenty hanks one bundle, and six bundles one packet; while in Scotland thirty-eight leas make one spindle, six leas one rand, twelve rands one dozen. The reel used is a long skeleton drum, capable of forming a score of hanks at one time. Though yarns of marvellous fineness have been made of flax, it is not usual to spin finer counts than 340 leas to the pound. The coarsest yarn made from pure flax is about twenty leas to the pound. Besides yarns intended for the loom, threads and twines of various kinds are made of flax. For the use of shoemakers a stout yarn of strong fibre is produced. This is slightly damped in spinning, so as to smooth down the fibres. From this yarn the shoemakers form "wax-ends," by placing together as many folds as are required for the work in hand, and then waxing and twisting them in a primitive manner. The extensive use of machinery in the shoemaking trade has, however, largely superseded hand labour and the old-fashioned wax-end, and now the thread is waxed and twisted by mechanism and supplied to the sewing machines on bobbins. For tailoring purposes various qualities of linen thread are made. In this case the fibre in course of being spun is passed through hot water, which makes the thread smooth and firm. Twine for the manufacture of fishing-nets is also made of flax. The threads and twines are made up in various ways—in hanks, balls, or on bobbins—according to the requirements of the purchaser. Most threads before being made up are boiled in soda lye to purify them to some extent, and it is at this stage that those intended to be coloured are dyed. For tailoring purposes the threads are used either in the "whitey-brown" state in which they are left by the first boiling, or they are dyed black or dark blue. Logwood, sumach, and copperas are the chief dye stuffs used; and soda lye, chlorine, and sulphuric acid for bleaching. The yarn is boiled or dyed in hanks, and after it has been dried it has to be twisted and rubbed in order to soften it. Some threads are polished to enable them to pass more easily through the material to be sewn, and this is done by coating them with wax, farina, &c., and subjecting them to the action of brushes in a machine specially designed for the purpose.

Flax is woven into a variety of fabrics suitable for a wide range of uses. The finest cloth made of it is cambric, which, in the form of pocket-handkerchiefs, has long been in favour. Of the same material, as well as of a heavier cloth, under-clothing of the best quality is made. For table use nothing yet introduced excels the beauty and purity of linen, and to its production in this form the aid of the artist as well as that of the mechanician has been invoked. Of heavier materials made of flax, it is unnecessary to mention more than sailcloth and sacking. Up till a comparatively recent time only the hand-loom was employed in the linen manufacture. When looms worked by power had been introduced into the cotton factories, it was hoped that the same machine could be made available for weaving linen; but experiments proved that this expectation was fallacious: at least, without some adaptations, which did not readily suggest themselves. So elastic is the fibre of cotton, that yarn formed of it will stretch considerably before breaking, and the same quality pertains to wool and silk; but flax is so consolidated, that if yarn made of it be stretched to the extent of even an inch to the yard, it will break. Owing to this peculiarity, the

warp threads snapped so frequently under the action of the treddles, that the work could not be carried on profitably. Other circumstances retarded the introduction of the power loom into the manufacture. One of these is thus explained by Mr. Charley :—" So long as a man's labour could be had at the hand loom in Ireland for a shilling a day, it was felt no power loom could work much, if at all, cheaper." In England and Scotland, however, labour was not so cheap, and mechanicians in those divisions of the kingdom applied themselves to the production of a loom that would deal successfully with the peculiarities of the flax fibre. Scattered references occur to improvements of the power loom in the way of adapting it to weave linen yarns; but up to the year 1812 none of these inventions appear to have succeeded. Mr. Warden informs us that "the first really successful manufactory for weaving flax goods by power was established in London in 1812 or 1813, when this country was in the very height of the struggle with Bonaparte. The factory was connected with the extensive rope-making works of Charles Turner and Co., Limehouse. The warp yarns were starched, and went through a laborious preparation, and the entire process would be reckoned very slow in the present day, but, for the period, displayed much mechanical skill and ingenuity. The yarns were chiefly spun by Neilson and Co., Kirkland Works, but towards the close of the war Messrs. Turner erected a mill for spinning their own yarns. At the peace of 1815 the demand for their goods ceased, and the spinning mill was stopped. The power looms, however, were kept on, and in 1832 they were still working, and at that time were making good canvas; but not long after they were stopped." In 1821 the linen manufacturers of Dundee and Kirkcaldy introduced the power loom into their factories, and from that time the use of the machine gradually extended to other centres of the trade in Scotland. The saving effected as compared with the work produced on the hand loom was reckoned at 25 per cent. A power-loom factory on a considerable scale was established at Aberdeen in 1824 by Messrs. Maberly and Co., and still exists, in a greatly extended form. "This establishment," says Mr. Warden, "may be called the parent of linen power-loom works of the country, because, from the great talent and mechanical skill which the proprietors employed, and the strong efforts they perseveringly made to adapt machinery to linen weaving, the obstacles which had previously barred its progress were obviated and success attained. This work is, therefore, perhaps the oldest linen-weaving establishment by power in existence."



Section of Tow-Carding Engine, showing Arrangement of Cylinders.

The power looms used in the linen manufacture are similar in the main to those on which cotton goods are woven. They are, however, stronger and heavier in their parts, and the warp is led over a vibrating roller, which accommodates the strain to the motion of the treddles, and so compensates for the want of elasticity in the fibre. The difference of cost between a power loom for cotton and one of the same width for linen is as £10 to £14. In preparing yarn for the loom it is first carefully boiled and washed, and if intended for white goods is bleached. The warp yarn is wound upon a roller by aid of the warping machine, and in this form is removed to the dressing room, where the yarn is unwound and drawn through a paste generally made of Irish moss, the well-known name for the dried leaves of the sea-weed *Chondrus crispis.* The dressing is dried by passing the yarn over heated rollers, from which it passes to the warp beam of

the loom. The weft meantime has been wound upon shuttle bobbins. The construction of the loom and the mode of placing the yarn upon it will be fully described and illustrated in the papers on "Cotton," so that it is unnecessary to go more into detail here. The fineness of linen cloth is regulated by different scales. The ordinary scale is 40 inches, and according to the number of warp threads used in that width the quality is denoted; but there is this anomaly in the naming: that a web with 2,000 threads in its width is called a ten-hundred ($10^{\circ\circ}$) web, because in putting it into the loom two threads are put through each opening in the reed. Glasses of a special kind are used to measure and count the threads in the cloth. The looms in which plain linens are woven are of the simplest construction, while those on which twills, diapers, and huckabacks are produced are more or less complicated.

Though the hand loom has been all but driven from the field by the steam-propelled machine, it becomes us to hold in grateful remembrance the useful part it played through so many centuries. Its capabilities in the hands of skilled operatives were far beyond what is generally believed. The history of the linen manufacture records many dexterous feats of weaving on the hand loom, and a few of these may be mentioned here. In the year 1702 a Dunfermline weaver made a seamless shirt in the loom, and a like feat was subsequently performed by other weavers in different parts of the kingdom. David Sands, of Kirriemuir, Forfarshire, invented in 1760 a mode of weaving double cloth for stay or corset makers, in which all the seams and sheaths for whalebone were perfectly formed, and little work was left to be performed by the seamstress. At a later period we are told that "he succeeded in weaving and finishing in the loom three shirts without seams. Not only did he weave the cloth, but he hemmed and stitched them, wrought button-holes, put on buttons, and also put ruffles on the breast, all in the loom. These wonderful productions of the loom were exhibited among his acquaintances, and he then sent one to the Board of Trustees for Manufactures, another to the Duke of Athole, and a third to the king. Whether any of the shirts are still in existence is unknown, but their ingenious maker died shortly after having accomplished this extraordinary work, poor in purse, though rich in local fame." Another Dunfermline weaver named Anderson produced in the year 1821 a shirt of a much more elaborate design. It was of very fine linen, and bore on the breast the British arms worked in heraldic colours and gold. For the accomplishment of this work Anderson received £10 from a fund created in Glasgow for encouraging improvements in the textile manufactures. The garment was presented to his Majesty George IV., who marked his appreciation of the ingenuity displayed in making it by a gift of £50. In later years Anderson produced on his loom a chemise for her Majesty Queen Victoria. It was composed of Chinese tram silk and net-warp yarn, and had no seams. The breast bore a portrait of her Majesty, with the dates of her birth, ascension, and coronation, underneath which were the British arms and a garland of national flowers. The flag of the Dunfermline Weavers' Incorporation is also mentioned as a remarkable piece of hand-loom work. It consists of a solid body of silk damask, bearing a different design on each side, and yet both are interwoven. The ingenuity displayed by the weavers of Dunfermline, in the instances referred to, was not a limited possession, for the manner in which the damask manufacture was taken up and developed in the town shows that the people generally possessed a natural aptitude for the work. In Ireland the hand-loom weavers do not appear to have sought a reputation for the production of "fancy work." What they vied with each other in was fineness of texture. In the year 1714 a weaver named Browne, who lived in the Lurgan district, became a person of much interest and importance through having produced what was then considered a marvellously fine specimen of cambric. Many persons travelled a long distance for the purpose of inspecting the web; and so widespread did the interest in it become, that Browne found it profitable to relinquish his loom, and make a tour through the north of the island to exhibit his handiwork. Though, no doubt, a marvel of fineness at the time, Browne's piece of cambric, being only what is known as a $16^{\circ\circ}$, would not now rank very high. Moses Fallis, of Waringstown, wove a web of $28^{\circ\circ}$ about the beginning of the present century, which was the finest piece of flaxen goods seen in Ireland up till that time. It sold for two guineas a yard, and was finally presented to the Princess Charlotte. "For many years afterwards the person who wove that unique piece of cambric, and Sarah Haughey, the woman by whom the yarn was spun, were local celebrities." By the year 1851 great progress had been made, and improved mechanism enabled the manufacturers to far out-distance the achievements of the hand-loom weavers of earlier times. From an account of the Irish exhibits at the Great Exhibition of that year, we quote the following passage in illustration of the fact

stated :—"The cambrics shown by Mr. Henning, of Waringstown, were objects of the greatest attraction to the trade, and especially to Continental makers. One of these was a 28$^{\infty}$ bordered handkerchief, the warp of which was 400 leas, and the weft 700 leas. The next was a 30$^{\infty}$ of the same maker and goods, with 550 leas warp, and 750 leas weft; and a third web was a 32$^{\infty}$, of 650 leas warp, and 850 leas weft. Still more attractive was a 36$^{\infty}$ handkerchief, the warp of which was 750, and the weft 1,000 leas. But the triumph of the whole was a plain cambric of 40$^{\infty}$ reed, the warp 900, and the weft 1,100 leas! The 36$^{\infty}$ handkerchief was the finest ever made in Ireland, and the plain cambric web was the highest set known to have been manufactured in any country. It was 16½ yards long, and when ready for the bleacher it was folded in a moderate-sized envelope, and forwarded through the post-office to Messrs. Charley, of Seymour Hill, and finished by those eminent bleachers in five days. For this unique specimen of Irish cambric the Exhibition jurists awarded Mr. Henning a gold medal."

IRON AND STEEL.—X

UTILISATION OF WASTE GASES, ETC.

By William Dundas Scott-Moncrieff, C.E.

We have already had occasion to speak of the importance of economising our supplies of coal, which are every year being reduced by millions of tons, and we will now give some account of the methods employed for doing so. In the great majority of cases in which coal is used for heating purposes, there is a difficulty in supplying a sufficient quantity of oxygen during the first stages of combustion. When what is called "green" coal—that is, fresh fuel—is thrown upon a fire or into a furnace, the heat immediately causes a great evolution of gas, and this is generally in excess of the amount of oxygen available for burning it. The consequence is that part of what ought to be used for raising heat in the fire or furnace escapes in the form of gas and carbon, and appears in the smoke that issues from our chimneys.

From a social point of view, it is almost impossible to over-estimate the nuisance that arises from the failure of science to solve this problem of complete combustion. Habit has accustomed the inhabitants of our large manufacturing cities to an amount of dirt and inconvenience which materially interferes with the common amenities of existence. The elements which all mankind—and, in fact, the whole animal kingdom—ought to enjoy as their birthright are denied to the wealthiest inhabitant of a manufacturing town. The light is obscured and the atmosphere polluted to an extent that accounts for many of the worst features of our social life. Among the labouring classes a winter spent in a large industrial centre is often a more trying ordeal, in all its essential elements, than banishment to the wildest and the most inhospitable regions of nature. Rising in darkness that is frequently rendered more obscure by smoke and exhalations, they return at night to breathe the same perpetual foulness. The conditions which produce lassitude among the educated and the wealthy, rendering change of air a necessity, cannot be supposed to leave those who are more constantly subjected to their influence unaffected by their continual presence. It seems unreasonable to expect that the prescriptions of the physician for the better classes, in the form of tonics, should not find their counterpart among the working classes in the shape of stimulants, with all their concomitant evils of drunkenness and crime. One may safely say that the moral effects of this failure of science to solve the problem of complete combustion are to be estimated as a great national calamity.

The physical results are even more apparent. The labour necessary to combat with the dirt arising from the smoke of a great city must of itself be equal to any one of its largest industries. Unfortunately, this labour falls to the share of those who are already over-burdened. It too often overpowers the exertions of the workman's wife, who at last gives up the contest, and contents herself with the constant contact of squalor. Let any one estimate for himself the money value represented by the labour necessary to clean the windows, and sweep the chimneys, and beat the carpets, and wash the extra linen of such a city as Manchester, and he will then discover the social importance of complete combustion. An apology for introducing the subject in this paper is to be found in the fact that the iron trade has hitherto been one of the principal offenders. It is enough to mention the "Black Country" as an instance of

its ravages, and to remind those who have travelled through its desolations, of the wilderness which is unrelieved by the shadow of a single tree, or the freshness of a patch of verdure. Since Science has made the world dirty, her next most pressing duty is to make it clean.

Many years ago I made experiments in a direction which, I believe, is more likely to lead to a radical cure of the evil than any other with which I am acquainted; and as an account of these will help to explain the true principles of complete combustion, I make no apology for giving a short description of them. In order to make certain that the gaseous products of the coal were fully consumed, I divided the process of combustion into two parts, the first of which consisted of separating the gas from the solid portions of the fuel known as coke, and afterwards burning the solid residue. For this purpose a retort, such as that which is commonly used in gas-works, was inserted in the furnace of an ordinary Cornish boiler, and the bottom of it was thus exposed to the action of the fire. The door of the retort, slightly projecting from the front of the boiler, was easily accessible, and afforded ready means of charging the retort with "green" fuel. A pipe was arranged, something like an ordinary gas-bucket, which could be swung towards the door of the boiler furnace, and, shortly after the retort had been charged, a large jet of gas issued from the nozzle, and was directed over the *burning coke of a previous charge.* It can be readily understood that it was an easy matter to admit sufficient air for the complete combustion of this continuous flow of gas, more especially as it passed over a fire of burning coke. In this way not only was the chimney free from the slightest appearance of smoke, but all the other products of the coal, consisting of tar, &c., were saved, and collected in a receptacle arranged for the purpose. As soon as the gas ceased to come from the retort, its contents, consisting of hard and brilliant coke, were removed and thrown into the furnace, where they became the means of consuming a fresh jet of gas from another charge. This double process could be carried on for an indefinite period. Although unable to follow up these experiments, I can still point to them as the only method I know of for producing complete combustion and taking the full advantage of it. In many branches of the iron trade, as well as in nearly every other industry requiring the consumption of fuel, this separation of the products of combustion into their solid and gaseous constituents will, no doubt, be ultimately adopted, but most probably not until some unfortunate victim is found who is ready to sacrifice his life and fortune in persuading traders that it possesses certain advantages.

The prevention of smoke arising from the use of coal for domestic purposes seems to me to depend upon the same conditions; and as every one would be the gainer by a system in which just so much gas was removed from coal as to prevent its smoking when freshly kindled, there seems to be no reason why it should not be adopted. If the laws were as stringent now as they were in the days of Edward I., probably some advances would be made, for that monarch prohibited the use of coal in London and its suburbs, "to avoid the sulferous smoke and savour of the firing." The process which is nearest to that just described has come into extensive use in the iron trade, and is known as the Siemens regenerative furnace, from the name of its well-known inventor.

This form of furnace has been extensively applied to the puddling process, and also to the method of producing steel with which the name of Dr. Siemens is more especially associated. In the earlier furnaces of the Messrs. Siemens, the plan adopted was simply to take advantage of the waste heat by passing it alternately first through one brick chamber and then through another, both of which exposed a great amount of surface. As soon as the waste heat was turned off from No. 1 chamber into No. 2, the air necessary for the combustion of the fuel in the furnace was passed through No. 1, and as it came in contact with the high temperature of the heated bricks, was converted into a species of hot blast. No. 2 chamber, in the meantime, having become heated by the passage of the waste heat, became the means, by the reversal of the valves, of heating the current of air when turned on in that direction. Certain difficulties which arose in applying this principle with solid coal led to the use of gaseous fuel and the introduction of gas-producers. These consist of combination chambers, in which the fuel is thrown in from the top, and being supplied with fire bars at the side near the bottom, admit of the coal being consumed in that direction. The combustion is carried on very slowly, and the volatile constituents of the coal, consisting of the ordinary products of a gas retort, pass on to the furnace, after being raised to a high temperature in one of the regenerators already described. An improvement upon this process was introduced shortly afterwards which

comes still nearer to a complete separation of the gaseous and solid elements of the fuel; but although a solid residue is saved, it is not afterwards employed as an essential part of the process, which only deals with the gases. This improvement consists of passing highly-heated air through the coal, so as to rob it of its gas, the necessary heat being obtained from regenerators, the temperature of which is entirely dependent upon the passage of the waste heat that would otherwise be lost. The elaborate details of the Siemens furnaces are arranged with the object of taking advantage of every chemical and mechanical combination that can possibly add to the heating value of the fuel, and the great economy obtained from the application of this system entitles its inventors to the foremost place among those who have attempted a solution of the difficult problem of complete combustion. The very number of these details is, however, one of the great defects of the system, as they are necessarily accompanied by a large amount of wear and tear, with much corresponding expenditure. The simplest method of obtaining the full effect of the waste heat in furnaces such as those which are used for puddling and heating iron seems to be that already suggested by my own experiments. In this way the gas is removed from the fuel, and the high temperature it receives from the waste heat is rendered available for the furnace, while the solid residue is preserved, and can be added to the combustion of the gas as it is required.

As we have already explained at some length, the greatest improvement that has been made in the direction of economising fuel in the iron trade is the hot blast, which has done more than all other appliances put together. It was very evident, however, that a great deal had still to be done, so long as the flames of the blast furnace and all the products of combustion, including an immense amount of heat, were allowed to pass freely into the open air, where they were lost for ever.

As generally happens, we find that the pressure of necessity was the first mother of improvements in the utilisation of the waste gases of blast furnaces, and that the earliest steps were taken where the pressure was most severe. As may be supposed, this was not likely to be in a country so well supplied with fuel as our own, and, accordingly, it is to France that we must look for the first efforts to utilise the waste heat of the smelting process. So early as 1811, M. Aubertot, who was the proprietor of iron works in the Department of Cher, obtained a patent for making use of the waste heat of blast furnaces, by employing it for the burning of lime or bricks, and also for the cementation of steel. He reserved only the latter application as his monopoly, and offered the rest of his invention to the iron trade, at the same time stating his readiness to give every information in his power. M. Aubertot had ample means at his disposal for testing the merits of his invention, as he possessed several iron works, or managed them; and before long there was a considerable interest excited with regard to its application.

The result of actual trials proved that the heat obtained from the waste gases arose not only from their high temperature, but from their capacity for combustion when exposed to a supply of air under suitable conditions. It does not appear how far the practice of M. Aubertot, and the interest which it had excited in France, led to the development of the system in this country, but we find that a patent was taken out by a Mr. Moses League so long ago as 1832, in which he proposed to apply the waste heat to the ovens of the hot blast iron, to save the fuel ordinarily employed for this purpose. A few years afterwards steam was successfully raised in boilers at the blast furnaces at Rustrel, in France, under the superintendence of an English engineer, and an arrangement of valves was then introduced which proved that the proper admixture of common air with the escaping gases was a necessary condition of success. In this country the principal credit of introducing this important source of economy rests with the veteran ironmaster, Mr. Budd, of Ystalyfera, in South Wales. He first made use only of the high temperature of the waste gases, as this was sufficient to heat the air required for the hot blast of the furnaces without their combustion. He afterwards employed the combustion of the gases for raising steam in the boilers required for driving the blowing engines, and his success led him to write as follows in 1848:—"It would appear to be more profitable to employ a blast furnace, if as a gas generator only, even if you smelted nothing in it, and carried off its heated vapours by flues to your boilers and stoves, than to employ a separate fire to each boiler and each stove. These considerations irresistibly suggest to me a great revolution in metallurgical practice; a new management, in fact, of furnaces and works, by which considerably above £1,000,000 a year might be saved in the iron trade alone."

This was written in 1848, and has since proved to be a correct prediction; but in spite of that, the open-mouthed furnace is still in vogue, belching

THE LANDORE SIEMENS' STEEL WORKS.

out flames and fumes, and will probably continue to do so until the generation that owns them has passed away for ever beyond the power of controlling their construction.

The most approved plan now adopted for removing the waste gases is that of drawing them off by means of a large pipe, formed of malleable iron plates riveted together, which branches away from near the top of the blast furnace; and the method of supplying the fuel and the charge of ores and limestone is that which has already been illustrated in the third chapter of this series. This is known as the cup and cone, and is exceedingly simple in its construction. It consists of a large cone of iron, which forms a sort of lid to the furnace, on the outside of which the proper amount of fuel and ironstone are allowed to rest until the moment the cone is lowered, when they all slip down for want of support, and fall into the furnace beneath. The raising and lowering of this cone is greatly aided by the back weight which is attached to the lever from which it is suspended, and the time occupied in the introduction of a new charge of fuel and ore is not more than a few seconds. The brazier, which is always kept burning over the top of the furnace, is placed there for the purpose of igniting the gases when they escape when the cone is lowered, as they would otherwise explode when mixed with a certain proportion of common air. There seems to be little doubt that in furnaces using the hot blast, and with a proper arrangement for consuming the waste gases so as to heat the ovens and raise steam in the boilers, the highest possible amount of economy is attainable, as there is nothing in the process which is inconsistent with the true principles of combustion. The solid residue of fuel in this case is, of course, required for the reduction of the iron ores to a molten state, and this goes on in the furnace itself.

It is sincerely to be hoped, for the sake of those whose lives are now spent in regions that are darkened by smoke and begrimed by soot, that some equally intelligent applications to science will be adopted in the other branches of the iron trade, as well as in every industry that requires the consumption of coal. And it is much to be desired that the welfare and comfort of the population should be at least as great an incentive to improvement in the future as the love of gain has been in the past.

WOOL AND WORSTED.—IX.

SHODDY AND MUNGO.

By William Gibson.

RAG-PICKERS are coeval with the paper manufacture, but this class of persons until the present century always carefully avoided rags made of wool, or even mixtures of wool and cotton, or wool and any other fibre, for the simple reason that they were considered almost valueless. But as paper-making progressed, and became remunerative, speculators began to ask themselves why the only rags to yield fortunes should be cotton ones. Was it not possible, for instance, to utilise cast-off coats, stockings, woollen hosiery, worn-out blankets, and discarded trousers? This question led to trials being made with the hitherto neglected materials, and, in course of time, to the establishment of an altogether new industry—the shoddy, mungo, and felt trades, and various occupations more or less intimately connected with them. Among the latter may be noted the numerous class of rag merchants all over the world, who, in their various localities, gather together the raw material—worn-out garments of all kinds, blankets, hosiery, &c.—and forward it to the manufacturing centres; the shoddy dealers in the commercial districts who receive the various consignments from agents widely scattered; and rag sorters who prepare the material for the manufacturers, of whom there are in the Batley district several hundreds, all employing a considerable number of hands.

These last-mentioned form an important factor in the shoddy trade. It is their business to sort the rags according to their colours, quality, hardness or softness; and, in case the consignment consist of garments, to cut out the seams, which they do rapidly and efficiently. It may, indeed, broadly be said that these work-people are, in the branch of manufacture with which we are dealing, as indispensable as the wool sorters in other branches of textile fabrication.

So far as we know, there is no direct evidence as to the person who first ground or tore up woollen

rags, and it is equally unknown at what precise date the operation was first undertaken. Probably many enterprising persons tried what they could make out of woollen rags, and not having succeeded, ceased further endeavours. What we do know is, if meagre, at least authentic. Some few furniture manufacturers—chiefly makers of bedding, mattresses, and stuffed furniture, in and around London, the chief seat of the paper manufacture of this country—and a few saddlers in the metropolis itself, used larger or smaller quantities of woollen "flocks" to mix with hair and other materials in their business. But up to the year 1813, nobody ever thought of applying the product to the cloth trade, until a Yorkshire manufacturer, merely by accident, saw a saddler employing it to stuff a piece of harness. The manufacturer referred to was Mr. Benjamin Law, who carried on business in Batley. Having occasion while in London to call upon a saddler, he saw one of the workmen using a material, totally new to him, of a long, woolly fibre resembling the material with which he was so familiar. On taking a handful from the heap to examine it, he found it really was wool, and he was led to ask a few questions as to where it came from and who manufactured it. He learned to his surprise that it was the outcome of old stockings, hosiery, or blankets. He thought it was capable of being spun, and, with the view of trying the experiment, sent an order to the person who sold it, and upon mixing it with a small percentage of new wool, wove it into a piece of cloth. This was in the year 1813. Mr. Law found a ready sale for his new product, at once invested the whole of his capital in the enterprise to which he had been led by a chance visit, and became the founder of the shoddy trade. Mr. Law was a native of Great Gomersal, a village near Bradford, and was born in the year 1772. Finding that he could produce more than he could dispose of in the English market, he sent his son John with a large consignment of goods to America, where he met with a ready sale at a good profit. A second venture in the same direction was agreed upon, and into this the original shoddy manufacturer put all his energy and all his money. His son started, no doubt with high hopes of success, and Mr. Law himself, in all likelihood, looked forward to securing the means of extending his business. Weeks passed away, but Mr. Law heard nothing of his son; and at length, fearing that he had died, or that some accident had happened which prevented his writing, determined to go out in search of the young man and his precious freight. He went to America, sought high and low, but no trace of his son or the goods could be found, and he returned home comparatively a ruined man. He died in Stockport in 1837, and was buried in the churchyard of Batley.* But the trade once started, many were willing to carry it on, and the result is that a large and continually increasing population has been drawn to Batley and the neighbouring villages, which are chiefly engaged in the shoddy manufacture.

Another name in connection with this branch of trade must be mentioned—that of Mr. Samuel Parr. To this gentleman belongs the honour of having introduced to the world the material known by the name of "mungo." This differs considerably from shoddy. Shoddy, properly so called, is a term applied to soft woollen rags, originally made of worsted, that have been torn to tatters, or ground into a sort of pulp in the "devil." Mungo is the name given to the same sort of material obtained from woollen rags, whether old coats, vests, trousers, or tailors' clippings. Mr. Parr introduced mungo in the year 1834. He offered a quantity of it for sale at Ossett, near Wakefield. Nobody cared about buying it, and one person is reported to have remarked to Mr. Parr, "I doubt it winnot goa." "Winnot goa!" replied the persistent salesman; "but it mun goa at som price." And "goa" it did; since when it has been known by the name of *mungo.* And although shoddy was first in the field, Mr. Parr's discovery has completely out-distanced it in the race of popularity, nine-tenths of the cloth now made in Batley and the district being of this material.

People used to have the notion that shoddy was a sort of felt, but that is not the case; others appear to think that it is entirely composed of old material worked up, and this is equally an error. All shoddy cloths have a larger or smaller percentage of new wool in them, and the better kinds are manufactured entirely from new lastings, tailors' clippings, and wool never used before. Shoddy really is only the short scraps that leave the "devil," although the materal in which it forms an ingredient bears the generic title.

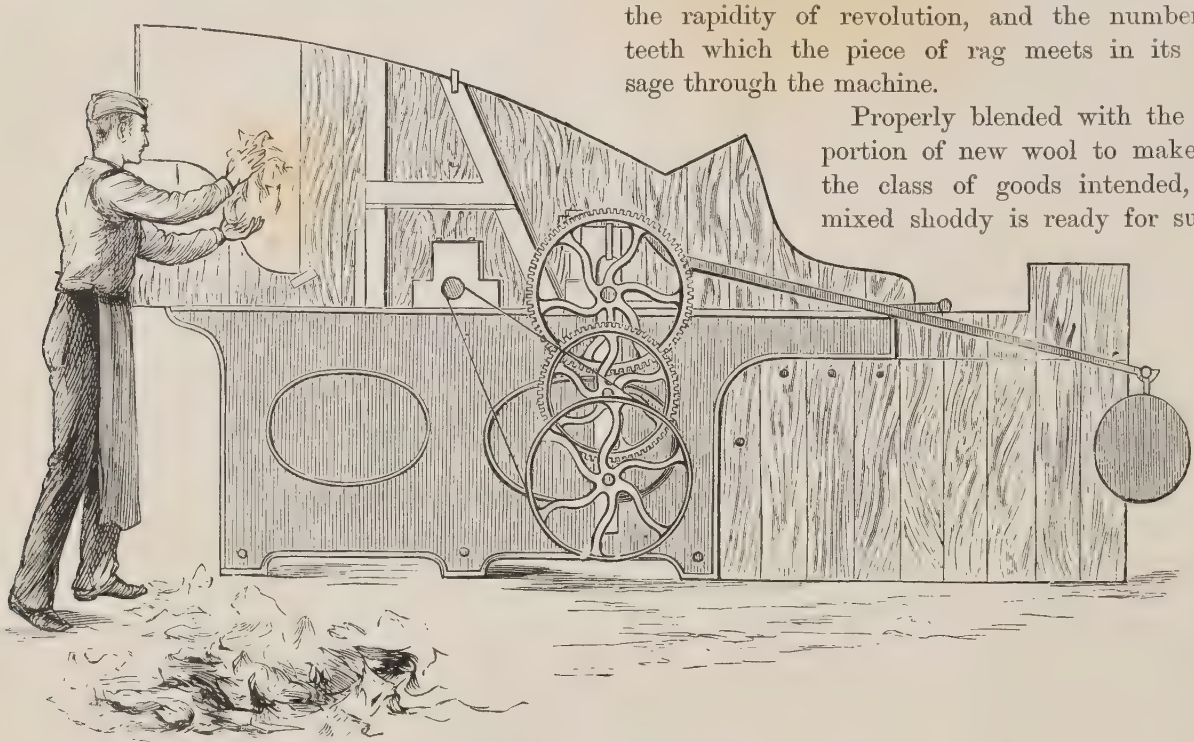
Shoddy or mungo reaches Batley in bales, and, so to speak, *in naturalibus*, with all its greasy and dirty admixtures. These bales are opened out, and the contents spread before women, who sort or pick them. The value of the rags varies, those brought from France, Germany, Belgium, Holland, and

* The writer is indebted to Mr. John Law, architect, Batley, great-grandson of the founder of the trade, for many of the facts in this sketch.

Scotland being the cleanest, while those imported from Ireland are the worst. These, mended, darned, dirty, and filthy to the last degree, give the pickers the greatest trouble; while the others for the most part are comparatively clean, and when "seamed" are ready for the next operation. The pickers sit upon low stools, almost hidden among mounds of rags, which they expeditiously assort according to quality and colour.

Grinding is the next stage in the manufacture. The machine by which this operation is performed in the shoddy trade is popularly called a "devil"—probably because it is a roaring lion devouring the pieces of cloth or worsted placed in its maw. Its function is to tear the cloth to tatters, and reduce it to something like the condition in which it was before originally being spun.

The rag machine, or "devil" as it is sometimes called, now in use in the Batley district, differs considerably from those with which Mr. Law and his contemporaries introduced shoddy to the world. The original machines were conical in shape, and the rags were torn to pieces by teeth set in plates in the interior, somewhat resembling doffing plates. When sufficiently "ground," they fell into a chamber through which a fan caused a stream of air to be driven. The material difference in the new machines is rather in detail than principle. Instead of being torn at the level of the ascending and descending revolution of the "swift" or spiked drum, the rags are now only torn in front of it, or at the centre of its ascending motion. But the machines in use to-day are much more efficient, because the number of teeth in the "swift" is greater, its speed has been largely increased, and the mechanical fans, for driving off the dust as the rags are torn asunder, much improved. The "swift" now contains as many as 12,000, and even 15,000 teeth, when used for mungo, and revolves at the rate of from 700 to 1,000 times per minute. The grinding, indeed, is mainly accomplished by the rapidity of revolution, and the number of teeth which the piece of rag meets in its passage through the machine.



The "Devil" Rag Machine.

Properly blended with the proportion of new wool to make up the class of goods intended, the mixed shoddy is ready for subsequent processes, which are identical with those characteristic of the cloth trade. The advantage of this coarser kind of cloth is that "shorts" and "noils," which would be useless in the worsted manufacture, are utilised here. "Shorts" are the coarser and shorter portions of fleeces used in the worsted trade unfit for combing, and "noils" are the refuse combings both of coarse and fine wools. Besides this, many coarse species of wool from Russia, Turkey, Egypt, and other countries, which worsted or woollen manufacturers could not use, are worked into the lower classes of shoddy fabrics. Of late years a large quantity of union cloths—composed of cotton warp and shoddy weft—have been manufactured, so that a considerable quantity of cotton thread is demanded in the district.

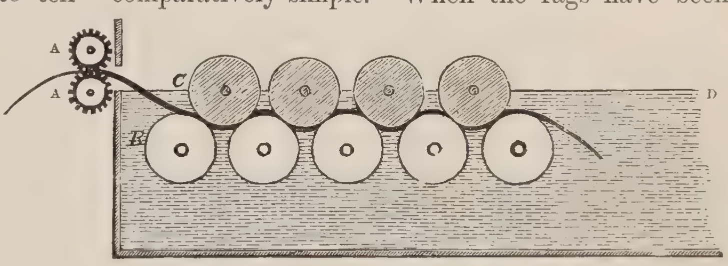
When the old clothes or rags have been "seamed"

for devilling, the seams are not thrown away. Indeed, nothing in the bales is wasted. The seams, after having been rotted, are used for manure, and sent particularly to the hop-grounds of Kent, and a selection of those from the best goods are ground to stuff mattresses and furniture. Shoddy dust, which comes from the rags while being "devilled," and that which falls from the "willy shaker," saturated with oil, form rich manure. More recently, the dry dust has been applied in the manufacture of what is known as "flock" paper hangings, and with it the best descriptions are obtained. Even shoddy after being worn is re-manufactured, especially the better sorts. Union cloth, however, was for a long time unable to be worked up again, the cotton warp being a barrier to the manufacture. Modern science has solved the problem, and to-day either the cotton can be destroyed by the help of acids, leaving the wool uninjured; or, should the cotton be the more valuable part of the cloth, the wool is singed into a cinder, while the former remains unaffected, and, of course, capable of doing fresh service. These processes of extraction have given the title of "extract" to the residue.

Shoddy is manufactured into many kinds of cloth, and, young as the trade is, some sorts made years ago have since been totally discarded. Among the kinds still most largely made are friezes, sent particularly to Ireland and America; witneys, either plain or in fancy styles, or in imitation of fur, chiefly used for ladies' cloaks and jackets; pilots—the staple of the shoddy trade—are made of various colours, but principally blue, black, and brown. They have a fine finish, are close cropped, and in great demand. The price ranges from one to ten shillings per yard, but most of the medium quality is sold. Army cloth—the sort from which soldiers' great-coats are made—engages many manufacturers; reversibles, or fancy cloth, much the same on both sides, and used for coatings, is extensively fabricated; cheviots and tweeds, of mixed colours, are produced to a considerable extent; and low-class cloth, for horse-rugs, linings, mop-cloth, floor-cloth, &c., occupies the attention of various firms.

Batley, so recently as 1841, had not more than 7,000 inhabitants; in 1860 it had risen to nearly 13,000; and in 1871 it was 20,871. Dewsbury, which had 8,000 souls in 1831, had 14,000 in 1851, and 24,764 in 1871. Heckmondwike had 4,500 in 1851, and in 1871 no less than 8,300. These figures indicate the strides which the shoddy trade has made; and this is still further borne out when we refer to the factory returns. Those for 1875 show that in England and Wales there were 123 factories, running 101,134 spinning spindles and 1,437 power looms, with 3,424 factory operatives. These, of course, only represent a small section of the work-people, for it may be said that at least one-fourth of the population of the districts in which the trade is carried on are directly engaged in it. Taking the years between 1871 and 1875, we find the following results:—In 1871 there were imported 24,219 tons of woollen rags, valued at £498,754; in 1872, 29,302 tons, worth £534,329; in 1873, 24,827 tons, at £468,556; in 1874, 25,581 tons, valued £547,399; and in 1875, 25,415 tons, worth £599,402. Probably we must add one-third at least to these figures, to allow for the home production, which will bring the total for 1875 up to 33,886 tons of rags, of the value of £799,202. Taking the details of the year 1875, we find that Germany sent us 6,899 tons, at £159,320; Denmark, 1,328 tons, at £27,086; Holland, 3,309 tons, at £87,947; Belgium, 4,500 tons, at £142,867; France, 7,335 tons, at £138,413; Italy, 360 tons, at £8,663; the United States, 397 tons at £8,660; and other countries, 1,377 tons, at £26,446—or an average of £23 10s. per ton.

Perhaps a few words ought to be said here about felted cloth, which is closely affiliated to the shoddy trade, inasmuch as it deals with the same sort of raw material. This manufacture is largely carried on at Leeds. Felted cloth is used for table covers, upholstery cloths, crumb cloths, carpets, and various other purposes. The processes of manufacture are comparatively simple. When the rags have been



ARRANGEMENT OF ROLLERS IN WARPING MACHINE.

properly ground, scoured, and cleaned, the wool is passed to immense carders, which deliver the material not in many narrow strips, but in one broad "sliver" or band several feet wide, and very little thicker than a cobweb. As the doffer knife frees it from the machine, it is wound on to a broad roller. A number of these rollers are then taken to a warping machine, where they are unwound simultaneously, the "sliver" of the second falling

on the first, and so on, till the required thickness has been obtained. For most materials this warping is seldom less than an inch thick. As this thick, soft band leaves the warping machine, it is made to pass between a pair of feed-rollers attached to a trough, a section of which is shown in the accompanying figure. The feeding rollers are at A, and the band passes between a set of rollers marked B and C, partially immersed in hot soapy water. Those marked B are hollow, charged with steam, and those marked C of solid wood. The rollers B simply revolve on their axis, but the others besides this have a "shogging" motion from side to side laterally, so as to rub the "sliver" and induce the fibres of the wool to felt. The sliver passes out at D fine thin felt. This is dried, pressed, printed in machines similar to those used by calico printers with the required pattern, or dyed one colour, as the case may be, pressed, and sent to market. The most inferior wools, noils, rags, and even admixtures of old flax and cotton, can be utilised by this process.

This naturally leads us to the manufacture of felt hats. Formerly the felting was done by hand pressure upon a mould shaped like a cone, with the apex round instead of diminishing to a point; but now one of the best machines is a very simple contrivance. Fed by an endless apron, the wool is carried into a chamber through which a strong current of hot air is forced by a mechanical fan. As only a very small portion of wool is admitted into this chamber at a time, in its course fibre is blown from fibre, till at the other end it is ejected a shower of wool. Close to the orifice by which it escapes is a huge perforated cone, round topped, and covered with a wet blanket, from the interior of which the air, as it revolves, is gradually pumped. This cone, or mould, revolves rapidly on its axis vertically, and the shower of wool as it leaves the hot-air chamber falls in flakes round the sides of the mould. The withdrawal of the air from the cone causes the fibres of wool to cling to the blanket, till a sufficient thickness has been obtained. The cone is now removed, and subjected to mechanical pressure in a hot bath till the clinging wool fibres have become a solid piece of cloth, when it can be moulded to the shape required. The bath, if the felt is to be soft, is merely soap and water; and if stiff, contains a glutinous substance, which binds the particles of wool during the process of felting, leaving it to retain its pliability long enough to admit of the future hat being moulded to the required shape. This branch of trade gives employment to a considerable number of people—felters, finishers, and women who sew on the binding, linings, &c., as well as those who fabricate the boxes used by hatters.

FOREIGN RIVALRIES.—V.

COTTON MANUFACTURE.

By H. R. Fox Bourne.

THOUGH wool was in former times the staple article of textile manufacture in Great Britain, with linen and silk in competition with it, cotton is now of far greater importance than all three put together. Of the entire produce of our textile manufactories the value of the cotton goods and yarns constitutes more than 67 per cent., while that of woollen and worsted materials, including carpets and the like, is only 23 per cent.; that of linen of all sorts, barely 7 per cent.; and that of silken fabrics considerably less than 3 per cent. The growth of our cotton industries during the past two or three generations is, indeed, one of the marvels of the history of trade. In 1820 our country produced over 108,000,000lb. of cotton yarn. That quantity was nearly quadrupled by 1840, and increased ninefold by 1860, when, on the eve of the cotton famine, the yield was about 966,000,000lb. Since then, the advance has not been great, but in 1876 it exceeded 1,131,000,000lb., about a fourth of which, as in former years, was exported, the rest being retained for working up at home. In 1850, again, we exported about 1,000,000,000 yards of cotton cloths, besides all that were consumed at home; and from that time, in spite of the disasters of the cotton famine, and the trade depressions of subsequent years, the quantity has increased on an average by just 100,000,000 yards a year. In 1876 it amounted to 3,669,404,374 yards, and had a declared value of £54,859,535. Taking piece goods and yarns together, we find that whereas in 1851 the total value of our exports was £30,088,836, it

had risen in 1871 to £72,678,945; and there was hardly any country in the world for which we did not cater very much more in the latter than in the former year. Our supply to Egypt was increased more than sixfold; to China and Japan, about fourfold; and to India, Australia, and many other parts about threefold; the European countries, as a whole, taking from us fully twice as much. In 1871, it has been estimated, each inhabitant of the world, including our own country, spent on British-made cotton goods, upon an average, nearly 1s. 2d., the proportion ranging from 1½d. in Russia, to 10s. 1d. in Australia, and being as high as 4s. 7d. in Mexico and the West Indies, 4s. 10d. in British North America, 5s. 9d. in South America, and 5s. 2d. in Germany, the last-named being our largest customer, with the exception of India and Ceylon.

With such figures before us as those from which we have taken the above illustrations, and with the knowledge that, if the spread of civilisation and the low price at which cotton garments can now be produced, have encouraged vast numbers of people to clothe themselves, there are vast numbers yet waiting to acquire this commendable habit, it may be thought that there is little ground for alarm as to much real injury coming to England from foreign competition in cotton manufactures. All the facts that we have to deal with, however, are not consolatory, and some of them, though they may not justify all the fears they have excited, are at any rate full of warning.

It is quite clear, in the first place, that Great Britain has lost the overwhelming supremacy, almost amounting to a monopoly, which it till lately enjoyed over the other countries of Europe. India has, of course, carried on from remote times an important cotton manufacture, though inadequate in quantity and unsuited in character to meet the wants of its own people. For many centuries after the introduction of the craft into Europe, England shared with some of the Continental nations the advantage of obtaining small quantities of Indian fibre to be spun and woven at home; and in recent times the demand for more cotton than the United States could furnish, especially during and since the period when the American civil war put a check upon the trans-Atlantic supplies, has given a great stimulus to the cultivation of the plant south of the Himalayas, in order that its produce may be sent to Europe. Neither of this Indian cotton nor of the exportations from Turkey, Egypt, and elsewhere, however, has England ever received a very great share. Large portions of them have gone to meet the wants of other countries, and, till lately, those wants were in large measure satisfied by importations from the East. It was different with the cotton grown in the West Indies, and afterwards to a very much greater extent in Virginia and other parts of the United States. Cultivated especially to answer the requirements of our own country, nearly all of this cotton was for a long time sent to it. This is no longer the case. Out of the 4,615,383 bales of cotton produced in the United States in 1876, nearly 30 per cent. was retained in the country itself; 10 per cent. went to France; more than 10 per cent. to the North of Europe; and more than 4 per cent. to other parts. England received only 45 per cent. That supply, it is true, exceeded 2,000,000 bales, to which was added, after deducting the quantity re-exported in a raw state, about 1,000,000 more bales, obtained from the East and West Indies, Brazil, and Egypt, so that the whole stock used up in England—3,095,000 bales, or about 60,000,000 lb. in all—was more than twice as great as that in all the rest of Europe, and about four times as great as that in the United States. It was hardly less, moreover, than the supplies of the previous four years, and far more than the country had been able to use up in earlier times; but this does not lessen the significance of the fact that the United States and several Continental countries have been increasing their importations, while England has barely maintained its level. In 1875–6, while it is estimated that in Great Britain there were 39,000,000 spindles, the following were the numbers set down for the other cotton-manufacturing countries in Europe:—France, 5,000,000; Germany, 4,650,000; Russia and Poland, 2,500,000; Switzerland, 1,854,091; Spain, 1,750,000; Austria, 1,555,000; Belgium, 800,000; Italy, 800,000; Sweden and Norway, 305,000; and Holland, 230,000. The number of spindles in the United States was 9,500,000—as many as those of the most active countries in Europe, France and Germany, put together.

It is not at all strange that the great American republic, having such rich stores of raw cotton at its hands, should endeavour to make up into clothing a sufficient quantity to supply, at any rate, the wants of its own people; and that it will do this in time, if it does no more, may be counted upon. The rapid progress made in recent years, however, has been altogether artificial, being due to the protective policy of the Government, which, if causing some injury to England, has done even yet greater harm to the country itself. On this subject some

sentences from the message of the Governor of New York, to the Legislature of that State, in 1877, are worth quoting. Referring to the trade depression consequent on the civil war, he said, "Individuals and corporations engaged in the various branches of manufacture, taking advantage of the necessities of the Government, rushed to congress, and by every means in their power, procured each for its own benefit the levy of what were called protective duties, under the false pretence of raising revenue for the Government, but really to compel consumers to pay exorbitant prices for the favoured articles. Under the stimulus of this so-called protection, new enterprises were undertaken, new and extensive factories built, and armies of labourers allured by high wages from fields of agriculture and other sober and rational employments of life. The few notes of warning raised against this wild over-action were unheeded. Extravagance of expenditure, the absence of everything like frugality and economy, obtained in all directions. The empty and delusive bubble thus raised could not endure, and although kept afloat by the whole power of the Government, so long as it was possible, it met at last the inevitable day of doom. Imaginary fortunes vanished in a moment, ill-advised schemes were suspended, and tens of thousands of innocent and unfortunate labourers were left without employment or the means of subsistence." Under the influence of these pernicious arrangements, America has lately manufactured cotton goods, chiefly of the rougher sorts, not only for the use of its own people, but also for sale in other countries. Its export trade in such cotton goods, during the past few years, has, indeed, increased with amazing rapidity. In 1872 it sent abroad, chiefly to the East Indies and South America, 11,704,000 yards; in 1874 the quantity had risen to 17,837,000 yards; in 1876, to 75,807,000 yards; and in 1877, to 105,831,000 yards. This steady movement requires some other explanation than that of the English optimists who assert that the goods which the Americans dispose of in English markets, at prices lower than English makers can afford, are only surplus stocks, which they find it better to part with at heavy loss than to keep idle in their warehouses. But it does not justify all the alarm which in some quarters it has stirred up; and, on the other hand, it must be borne in mind that America still finds it necessary to obtain from Europe, in large quantities, the finer fabrics which the native factories are unable to supply. "As regards their own markets," says Mr. Isaac Watts, of Manchester, "the manufacturers of the United States hold the supremacy, not on account of the superior excellence or greater cheapness of their goods, but solely through the rigid exclusion of foreign and competing fabrics. Their tariff is arranged expressly to prevent competition, and to insure to native producers a complete monopoly, so that if English-made goods appear in these markets, the purchaser must pay for them from 30 to 50 per cent. more than he otherwise would do. This addition of 50 per cent. more or less, is not to be attributed merely to the greed of the American manufacturers—it is not so much extra profit which he obtains at the expense of the consumers—but it is owing chiefly to his inability to produce the goods as cheaply as his foreign rival, and the remedy is obtained by keeping that rival altogether out of the market. As regards America, therefore, it is not a question of competition at all, but of exclusion and prohibition; and whenever this shall cease, and equal terms be secured, England will have no reason to be afraid of the issue. She is not now beaten in the contest, but only kept out of the field by impenetrable barriers. The policy itself is sufficient indication of the views which prevail in America as to the ability of England to compete with her manufacturers. Neither in the raw material, machinery, skill, nor cost of labour, have American manufacturers any special advantages, whilst in some respects they are less favourably circumstanced than their English rivals. Nothing but abandonment of the system of exclusion, now so rigidly upheld, is wanted to render the trade with America as extensive and important as that which England carries on with any part of the globe." If that anticipation is somewhat too sanguine, it may be taken for granted that when the Americans have discovered the folly of their protective policy, affairs will so far right themselves as to give England a sure footing in the honourable competition between the two nations.

In Germany and the other Continental countries which rely especially on protective duties to assist their trade in cotton goods, the main conditions are to a great extent the same as in the United States. As regards France, our chief Continental rival in this branch of manufacture, and such other countries as Switzerland and Belgium, the case is different. Mr. Hugh Mason, a great practical authority on this subject, though hardly to be implicitly followed in his economical views, published in March, 1877, the results of his inquiries into the condition of the French as compared with the English cotton trade. "The French spinner, he said, "is at no disadvantage

whatever in the cost of building his factory and of fixing such plant as steam engines, boilers, and main gearing. When the factory has been built and fitted up, it must be fitted with machinery; and there is no doubt that French machinery of the present day is in all respects as good and as cheap as the English spinner can buy. Indeed, in a very few important appliances in the carding room the French have lately taught the English some useful and practical lessons. Up to the point of the factory being ready to card the cotton and to spin the yarn, the French spinner is on a par with his English rival." In some other respects he appears to have a distinct advantage. It is unfair, of course, to compare the wage rates of the two countries without taking account of the working capacities of the inhabitants. But no one can suppose that the services of an English grinder at 24s. a week, are as cheap as those of a Frenchman at 10s., or that a French roller coverer is not likely to do more than 63 per cent. as much work in a week, for which he is paid 19s., as an Englishman, who receives 30s. "In a factory of 50,000 spindles," says Mr. Mason, "30 minders will be required, giving 1,680 spindles to one minder. There is no difference in the two countries in the number of spindles put under the control of one minder. The French pay their 30 minders in wages the sum of £1,852 a year. The English pay their 30 minders £2,652 a year. Let the same tests be applied to other departments of labour, and the result will show that the French capitalists will make good profits when the English capitalists would be ruined. I have made this comparison, so far very unfortunate to the English spinner, on the basis that the English and French factories are equal in hours of labour. When, however, the actual hours of work are counted, the contrast becomes startling. The English factory works 56 hours a week, or 2,912 hours a year. The French factory works 66 hours a week, or 3,432 hours a year. Here it is that the dead weight of high-priced labour becomes so burdensome to the English spinner. The French pay the 30 minders £1,852 for working 3,432 hours, and the English pay £3,125 for the same number of hours. This is in one department of labour." After saying much else to strengthen his argument, Mr. Mason adds:—"In my comparison of English and French factories, I have not taken extreme cases; I have compared a well-managed modern factory in Oldham with a similar factory in a well-known town in France, and my comparison will be found to be a fair one for three-fourths of the entire trade in the two countries." It must be remembered, however, that if the lower wage rate in France helps to make French cottons cheap, a much more important item in the calculation is the fact that the lower rate of interest in France compels the French employer to be satisfied with smaller profits than would content an English capitalist.

If the industrial supremacy of England has hitherto given it an advantage over not only France, but all other countries as well, and has thus induced both employers to look for greater profits, and workmen to look for higher wages, than are elsewhere to be obtained, until their very elements of success have become sources of weakness to our cotton trade in its competition with that of other countries, it must be remembered that whatever danger hangs over it is still more due to other causes. High wages may be cheaper than low wages, if the workman to whom they are paid makes adequate return for them by showing superior skill and energy in his craft, and large profits may be safely insisted upon if they are earned by the shrewdness and honesty of the employer. In these respects both masters and men in England may at the present time be as deserving as they or their fathers were in former years; and yet both will suffer if foreigners learn to vie with them in the exercise of these qualities. There can be no doubt that, though improvements in machines may give special advantages to those who start them, they tend, as they come into general use, to reduce the relative value of physical, if not also of intellectual and even moral, superiority. Good tools lessen the inequality between a bad workman and a good one; and the possession of the best machinery may, to a great extent, supply its owner's lack of brains. If that is true of individuals, it is as true of nations. Whether or not there is still among Englishmen as much superiority in industrial capacity as they used to be credited with, machinery has greatly assisted other people in competing with them. Testimony to this effect might be given in abundance; but a few sentences from official reports made to our Government will suffice. Mr. Redgrave, the factory inspector, who went a few years ago on a special visit of inquiry to France and Belgium, for instance, speaking of "the increased and increasing size of factories" in those countries, says that "a few years have made a great difference, and now the commercial arrangements of a French and Belgian factory bear no mean comparison with our own." In Switzerland, Mr. Gosling reports, though machinery and coal are

much dearer than in England, the skilful use of water power more than compensates for this, so that "the balance seems to be greatly in her favour, and under present circumstances cannot fail to become still greater from day to day." In Germany, protection cripples the trades it is meant to cultivate, but they make progress in spite of it. "The producing power of the Prussian spinning and weaving factories is decidedly on the increase," says one authority, the reason being that "machinery has been generally much improved." In Bavaria, according to another, there are "factories supplied with the best and newest machinery, in which only about half the number of workmen are required for the same amount of production as were necessary twenty years ago with the machinery then in use." From other countries the reports are to the same effect.

There is so much resemblance, in some respects such identity, between the conditions of cotton manufacture and those under which other textile fabrics are produced, that our notice of some elements of rivalry may be conveniently deferred until those other fabrics are treated of. In the manipulation of silk and linen, for instance, we see more plainly than in that of cotton the disadvantages under which England competes with some other countries through want of artistic refinement and through inaptness in catering for the peculiar tastes, good or bad, of foreign customers. There is one danger ahead, however, which applies especially to cotton manufacture, and which, though it has nothing to do with art, partly arises from unwise efforts to satisfy a more or less perverted taste. In endeavouring to produce showy goods at the lowest possible cost, manufacturers are encouraged to resort to tricks of all sorts, which, however profitable at the moment, are sure to be prejudicial in the end; but which, for all that, there is a fatal temptation to emulate. Discreditable as the fact is, it is still a fact that the reputation formerly acquired by England for the excellence of its goods is now often used only to palm off goods of inferior quality. If this continues, the result cannot be uncertain, and in some instances it is already showing itself very plainly. Thus, Mr. A. J. Wilson writes as follows, in his able work on "The Resources of Modern Countries," which appeared early in 1878:—"China is our second best customer for plain cotton fabrics, coming next to India, and the loss of her trade, or any part of it, would be assuredly most seriously felt. Several causes, independent of the financial position and of our own folly, combine to render our hold of the trade and our power to expand it much less assured than it was a few years ago. Chief of them appears to be our own dishonesty. We have in the greedy, unscrupulous competition which modern business habits have introduced into all departments of trade, made and sold to the Chinese bad, heavily-sized fabrics, to an extent that has discredited our productions as against both the coarser but cheaper and stronger home-made tissues and the better-made cottons of the United States. The Chinese are large growers of cotton, and probably about four-fifths of the entire consumption of cotton cloths are still of home manufacture—in the interior of China, at all events. Whatever depreciates the character of our goods must necessarily perpetuate the disposition to prefer the home-made fabrics to ours. In time, however, this mischief of dishonest fabrics would perhaps cure itself by the ruin of the mischief-makers, were there no other element of danger to fight against than native competition. But both the Americans and the Dutch, and to some extent the Germans, now compete with us in the Chinese markets, and, though none of them make much way, both the Americans and the Germans appear to compete with at least a promise of success." It is for English manufacturers to consider whether, besides all the legitimate obstacles that they have to overcome in this competition with foreigners, they will, by forfeiting their old character for honesty and good workmanship, inflict upon themselves far greater injury than the worst that can result from other causes.

END OF VOLUME I.